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Region 2 RAC2
Remedial Action Contract

Final Screening Level Ecological Risk Assessment

Maunabo Groundwater Contamination Site

Remedial Investigation/Feasibility Study

Maunabo, Puerto Rico

WA No.: 014-RICO-02XF

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Table of Contents

List of Tables

List of Figures

Appendices

Acronyms and Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
BERA	baseline ecological risk assessment
BTAG	Biological Technical Assistance Group
CDM Smith	CDM Federal Programs Corporation
COPC	chemical of potential concern
CSM	conceptual site model
DCE	*cis*-1,2-dichlroethene
EPA	United States Environmental Protection Agency
ERAGS	Ecological Risk Assessment Guidance for Superfund
ESL	ecological screening level
FSM	former sugar mill
HQ	hazard quotient
MCL	maximum contaminant level
MTBE	methyl tertiary butyl ether
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PRASA	Puerto Rico Aqueduct and Sewer Authority
PRB	Puerto Rico Beverage
PRDNER	Puerto Rico Department of Natural and Environmental Resources
PRDOH	Puerto Rico Department of Health
PRIDCO	Puerto Rico Industrial Development Corporation
RAC	Remedial Action Contract
RI/FS	remedial investigation/feasibility study
SAT 2	Site Assessment Team 2
SLERA	screening level ecological risk assessment
SMDP	scientific management decision point
SVOC	semi-volatile organic compound
TAL	target analyte list
TCL	target compound list
USFWS	United States Fish and Wildlife Service
VOC	volatile organic compound
µg/kg	microgram per kilogram
µg/L	microgram per liter

Executive Summary

CDM Federal Programs Corporation (CDM Smith) received Work Assignment Number 014-RICO-02XF under the Remedial Action Contract (RAC) 2 program to provide technical services to complete a Remedial Investigation/Feasibility Study (RI/FS) for the Maunabo Groundwater Contamination site (the site) for the United States Environmental Protection Agency (EPA), Region 2. The site is located in Maunabo, Puerto Rico.

The overall purpose of the work assignment is to evaluate the nature and extent of contamination at the site and to develop and evaluate remedial alternatives, as appropriate. This Screening Level Ecological Risk Assessment (SLERA), as part of the RI/FS, provides a preliminary evaluation of ecological risks from contaminants to terrestrial and aquatic environments present within the study area.

The objective of this SLERA is to evaluate the potential for risk at the site. Conservative assumptions are used to identify exposure pathways and, where possible, quantify potential ecological risks. This report is prepared in accordance with the following documents:

- Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final (EPA 1997)
- Guidelines for Ecological Risk Assessment (EPA 1998)

Site Background

Maunabo's public water system, known as Maunabo Urbano, consists of four groundwater wells: Maunabo #1, Maunabo #2 (Bordaleza), Maunabo #3 (Calzada), and Maunabo #4 (San Pedro). In March 2002, the Puerto Rico Department of Health (PRDOH) ordered the Puerto Rico Aqueduct and Sewer Authority (PRASA) to close Maunabo #1 due to concentrations of tetrachloroethene (PCE) above the federal Safe Drinking Water Maximum Contaminant Level (MCL). Due to water supply needs, PRASA opted to treat the groundwater rather than close the well. Subsequent investigations determined that treatment attempts were ineffective as PCE and other chemicals were still detected in both groundwater samples from Maunabo #1 and in post treatment samples taken from distribution lines. However, PRASA has since installed a new carbon treatment system which is functioning properly. Regardless, results of these investigations indicated there was insufficient information to conclusively determine the source(s) of contamination of the drinking water supply wells.

Site Description

The site is located within an isolated alluvial river valley, and is surrounded by mountains to the north, east, and west, and the Caribbean Sea to the southeast. The Maunabo River and several intermittent streams are located within the vicinity and flow southeast toward the Caribbean Sea. Groundwater discharge generally forms the baseflow of the river, and also discharges to smaller tributaries and streams (quebradas) such as Quebradas Arenas. However, during dry periods and in the vicinity of a pumping well the river is sometimes losing to the groundwater. Land use is primarily agricultural intermixed with some residential, commercial, and light industries.

Ecological Reconnaissance and Presence of Threatened and Endangered Species

An ecological reconnaissance was performed at the site, and focused on undeveloped portions of the study area, more specifically, aquatic and riparian habitats of the Rio Maunabo and Quebrada Arenas. In addition, information regarding threatened and endangered species and ecologically sensitive environments that may exist at or in the vicinity of the site was requested from the EPA and the Puerto Rico Department of Natural and Environmental Resources (PRDNER).

The EPA reported that a review of United States Fish and Wildlife Service (USFWS) records indicated that five federally-listed species can be found within the municipality of Maunabo. These species include four coastal species, the green sea turtle (*Chelonia mydas*), leatherback sea turtle (*Dermochelys coriacea*), hawksbill sea turtle (*Eretmochelys imbricate*), and the West Indian manatee (*Trichechus manatus manatus*). Since the site is located more than 0.5 miles from the coast no impacts to these species are anticipated. The fifth species is Guajon or Puerto Rican Demon (*Eleutherodactylus cooki*). Review of critical habitats maps in relation to the project area indicated that this species is not in close proximity to the site.

The PRDNER reported that a review of their records for the site and surrounding area indicated no known occurrences of listed rare, threatened, and/or endangered species.

Assessment and Measurement Endpoints

For this SLERA, the following assessment endpoints and measurement endpoints were selected to evaluate whether site-related contaminants pose a risk to ecological receptors:

- Assessment Endpoint 1: Viability (survival, growth, and reproduction) of terrestrial ecological receptors/communities

Measurement Endpoint: Evaluate the toxicity of contaminants in soil by comparing maximum detected concentrations to soil-specific ecological screening levels (ESLs)

- Assessment Endpoint 2: Viability (survival, growth, and reproduction) of aquatic ecological receptor/communities

Measurement Endpoint: Evaluate the toxicity of sediment, surface water, and porewater by comparing maximum-detected concentrations to sediment- and surface water-specific ESLs.

Data Used in the Screening Level Ecological Risk Assessment

The SLERA evaluated exposure to chemicals through direct contact with site media. All data used in the SLERA was collected in support of the RI. The following samples were collected and evaluated in this SLERA:

- 12 surface soil

- 6 sediment (does not include 1 background sample)
- 6 surface water (does not include 1 background sample)
- 5 porewater

For this SLERA, a single maximum value for each medium type evaluated was selected.

Summary and Conclusions

Based on a comparison of maximum detected concentrations of contaminants in site soil, sediment, surface water, and porewater to conservatively derived ESLs, the potential for ecological risk may occur. Specifically, hazard quotients (HQs) > 1.0 were calculated, which indicate potential risk from exposure to the following media-specific contaminants:

- **Soil:** cadmium, chromium, copper, lead, manganese, mercury, vanadium, and zinc
- **Sediment:** copper
- **Surface water:** barium
- **Porewater:** aluminum, barium, and iron

Potential risk from the following media-specific contaminants cannot be concluded as ESLs are not available for these compounds:

- **Soil:** carbazole
- **Sediment:** barium and vanadium
- **Surface water:** bromodichloromethane and dibromochloromethane

Chemicals of potential concern (COPCs) retained via comparison to their respective media-specific ESLs were all comprised of metals. The remaining COPCs, which included the organic compounds carbazole, bromodichloromethane, and dibromochloromethane were all retained as COPCs due to a lack of media-specific ESLs. No site-related chemicals (e.g., PCE and DCE) were detected in any medium evaluated in this SLERA. Those metals detected above conservative ESLs are most likely reflective of natural conditions, or non site-related sources. Therefore, the site poses no site-related risk to ecological communities present.

Section 1

Introduction

CDM Federal Programs Corporation (CDM Smith) received Work Assignment Number 014-RICO-02XF under the Remedial Action Contract (RAC) 2 program to provide technical services to complete a Remedial Investigation/Feasibility Study (RI/FS) for the Maunabo Groundwater Contamination site (the site) for the United States Environmental Protection Agency (EPA), Region 2. The site is located in Maunabo, Puerto Rico (Figure 1-1).

The overall purpose of the work assignment is to evaluate the nature and extent of contamination at the site and to develop and evaluate remedial alternatives, as appropriate. This Screening Level Ecological Risk Assessment (SLERA), as part of the RI/FS, provides a preliminary evaluation of ecological risks from contaminants to terrestrial and aquatic environments present within the study area.

1.1 Objectives

The objective of this SLERA is to evaluate the potential for risk at the site. Conservative assumptions are used to identify exposure pathways and, where possible, quantify potential ecological risks. This report is prepared in accordance with the following documents:

- Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final (EPA 1997)
- Guidelines for Ecological Risk Assessment (EPA 1998)

The SLERA consists of Steps 1 and 2 of a recommended eight step process for conducting ecological risk assessments at Superfund sites (EPA 1997). Step 1 of the Ecological Risk Assessment Guidance (ERAGS), includes a screening level problem formulation and ecological effects evaluation. Descriptions are developed of:

- Environmental setting
- Contaminants known or suspected to exist at the site and the maximum concentrations present in each medium
- Contaminant fate and transport mechanisms that might exist
- Mechanisms of ecotoxicity associated with contaminants and categories of receptors that may be affected
- Potentially complete exposure pathways

In Step 2 of the ERAGS, the screening level preliminary exposure estimate and risk calculations, risk is estimated by comparing maximum documented exposure concentrations with the ecotoxicity screening values identified in Step 1. The process concludes with a scientific management decision point (SMDP), which determines that:

- Ecological threats are negligible
- Ecological risk assessment should continue to determine whether a risk exists
- There is a potential for adverse ecological effects, and a baseline ecological risk assessment (BERA), incorporating more site-specific information, is needed.

Per EPA's ERAGS (1997), a SMDP will be made by risk managers.

1.2 Report Organization

This SLERA is composed of eight sections and three appendices including:

Section 1	Introduction – provides an overview of the objectives and organization of the report.
Section 2	Problem Formulation – presents the environmental setting, conceptual site model (CSM), assessment and measurement endpoints, risk questions, overview of data evaluated in the SLERA.
Section 3	Exposure Assessment – presents the pathways and media through which receptors may be exposed to site contaminants.
Section 4	Effects Assessment – presents the literature based- and chemical-specific ecological screening levels (ESLs) for detected chemicals.
Section 5	Risk Characterization – presents the process for selecting chemicals of potential concern (COPC), and integrates information from the exposure and effects assessments.
Section 6	Uncertainty Assessment – discusses the uncertainties associated with the assumptions used in this SLERA.
Section 7	Summary and Conclusions – summarizes the significant findings of the SLERA and makes conclusions based on the results.
Section 8	References – provides a list of references cited.

Tables and figures are presented at the end of the text. In addition, Appendix A presents letters received from the Puerto Rico Department of Natural and Environmental Resources (PRDNER) and EPA regarding Puerto Rico and federally-listed threatened and endangered species at or in the vicinity of the site. Appendix B includes the analytical results of media evaluated in this SLERA. Fate, transport, and toxicity information for COPCs is included in Appendix C.

Section 2

Problem Formulation

The problem formulation contains a description of the environmental setting, CSM, assessment and measurement endpoints, risk questions, and an overview of data evaluated.

2.1 Environmental Setting

This subsection describes the site location and description, site history, site geology and hydrogeology, ecological habitat and biota, and threatened and endangered species that may occur at or in the vicinity of the site.

2.1.1 Site Location and Description

The Maunabo Groundwater Contamination site is located in the municipality of Maunabo, situated in the southeastern coastal area of Puerto Rico (Figure 1-1). The site consists of a groundwater plume with no identified source(s) of contamination. The size of the plume has not been determined.

The site is located within an isolated alluvial river valley, and is surrounded by mountains to the north, east, and west, and the Caribbean Sea to the southeast. The Maunabo River and several intermittent streams are located within the vicinity and flow southeast toward the Caribbean Sea. Groundwater discharge generally forms the baseflow of the river, and also discharges to smaller tributaries and streams (quebradas) such as Quebradas Arenas. However, during dry periods and in the vicinity of a pumping well the river is sometimes losing to the groundwater. Land use is primarily agricultural intermixed with some residential, commercial, and light industries.

2.1.2 Site History

Maunabo's public water system, known as Maunabo Urbano, consists of four groundwater wells: Maunabo #1, Maunabo #2 (Bordaleza), Maunabo #3 (Calzada), and Maunabo #4 (San Pedro). In March 2002, the Puerto Rico Department of Health (PRDOH) ordered the Puerto Rico Aqueduct and Sewer Authority (PRASA) to close Maunabo #1 due to concentrations of tetrachloroethene (PCE) above the federal Safe Drinking Water Maximum Contaminant Level (MCL). Due to water supply needs, PRASA opted to treat the groundwater rather than close the well. Detections of PCE in groundwater samples from Maunabo #1 have exceeded the MCL several times, indicating that attempts to treat the water were ineffective. However, PRASA has since installed a new carbon treatment system which is functioning properly.

In October 2005, EPA's Region 2 Site Assessment Team 2 (SAT 2) collected water samples from each well, and from the distribution water line. Results indicated the presence of PCE, cis-1,2-dichloroethene (DCE), and methyl tertiary butyl ether (MTBE) in Maunabo #1, and in post treatment samples along the distribution line at levels below their respective MCLs. In addition, 1,1 DCE was also detected in Maunabo #4 at levels below its federal MCL.

In December 2005, the SAT 2 conducted an investigation of possible sources of groundwater contamination at five industrial sites around the Maunabo area. Facilities investigated included the former Maunabo Municipal Solid Waste Landfill, PRASA's Wastewater Treatment Plant, El Negro Auto Body/Parts shop, Total Gas Station, Esso Gas Station, and five light industrial facilities operating under the auspices of the Puerto Rico Industrial Development Corporation (PRIDCO).

Results of the October and December 2005 investigations indicated there was insufficient information to conclusively determine the source(s) of contamination of the drinking water supply wells. Subsequently, the Agency for Toxic Substances and Disease Registry (ATSDR) evaluated available data, and conducted a site visit to complete a Public Health Assessment. Results of the Public Health Assessment concluded that the wells exceeded EPA's MCLs for PCE and DCE in the past, however, exceedances were intermittent and did not exceed ATSDR's health based comparison values, and that current and future conditions at the site present no apparent public health hazard.

2.1.3 Site Geology and Hydrogeology

This section provides a brief summary of the lithologic and hydrogeologic characteristics of the site and immediate area. A more detailed description of site geology and hydrogeology can be found in the RI report.

2.1.3.1 Site Geology

The site is located within an alluvial valley surrounded by hills composed of igneous plutonic rocks. The two strata encountered at the site are the Quaternary-age alluvium deposits and the underlying Late Cretaceous-age igneous plutonic rocks mapped as the San Lorenzo Batholith (Rogers et al. 1979). Tonalite outcrops of the Punta Guayanes Complex are located southwest and southeast of the site. Other units near the site consist of metavolcanic rocks to the southwest and small outcrops of metamorphic amphibole hornfels to the west and southeast of the site. The units expected to be found beneath and adjacent to the site are described below.

Quaternary Alluvium Deposits

The Quaternary alluvium deposits consist of unconsolidated silt, clay, sand, and gravel and underlie the Maunabo River valley. The lithology varies widely with numerous discontinuous lenses of clay, silt, and sand. The thickest and most permeable deposits are located within the buried ancestral bedrock valleys and can be up to 200 feet thick (Adolphson et al. 1977).

San Lorenzo Batholiths

The San Lorenzo Batholtih, covering an area of 200 square miles, is one of the most geologically prominent features in southeastern Puerto Rico. The batholith, formed during the Late Cretaceous Age, is composed of three major units, which in chronological order (oldest to youngest) include diorite and gabbro, the San Lorenzo granodiorite and tonalite, and the Punta Guayenes plutonic complex. The Punta Guayenes complex ranges from tonalite to quartz monzonite and is generally concentrated in the outer portion of the batholith (Rogers et al. 1979).

2.1.3.2 Site Hydrogeology

Groundwater is most abundant in the shallow unconfined alluvial aquifer of the Maunabo River valley. The underlying igneous plutonic bedrock yields generally small to moderate quantities of water.

Groundwater flow within the alluvium was determined to be at an oblique angle toward the river in the direction of river flow (Adolphson et al. 1977).

2.1.4 Habitat and Biota

Study area habitats were identified based on an ecological reconnaissance performed for the site on November 4, 2009. Information regarding habitats and biota observed are discussed in this section. The ecological reconnaissance focused on undeveloped portions of the study area, more specifically, aquatic and riparian habitats of the Rio Maunabo and Quebrada Arenas since these areas are where ecological receptors would be most prone to exposure from contaminants present in groundwater discharge. During the ecological reconnaissance no observations of groundwater discharge or seeps were noted.

Rio Maunabo

The Rio Maunabo can be classified as a moderate gradient, urban stream situated in a well defined channel where it flows through the municipality of Maunabo. Several roads, residences, agricultural properties and industries are within close proximity of the river. During rain events, sheet flow and storm water is most likely conveyed into the river from these surrounding areas.

Within the area of the ecological reconnaissance, river substrate consists primarily of medium to coarse sand. In general, water depth is limited to a few inches; width is variable and ranges from approximately 15 to 25 feet. The sandy substrate, wide channel, and shallow water create conditions favorable for the formation of exposed sand flats. No aquatic vegetation was observed during the field event. River banks are steep and heavily vegetated. Where intact, riparian vegetation consists primarily of two distinct communities; herbaceous growth intermixed with sporadic trees such as black mimosa (*Mimosa pigra*), coconut palm (*Cocos nucifera*), sierran palm (*Prestoea acuminate*), African tulip tree saplings (*Spathodea campanulata*), and tropical almond (*Terminalia catappa*) along with some shrubby species, and dense monotypic stands of bamboo (*Bambusa* spp.). Transition from riparian to upland vegetative communities, in general, is lacking as in most instances riparian habitats abruptly end at the top of the river banks where they are bounded by agricultural or residential properties.

Little wildlife was encountered within the area. Small crabs and fish were observed sporadically within the river. Birds observed consisted of gray kingbird (*Tyrannus dominicensis*), an unidentified wading bird in flight, a species of hawk, and egret. With the exception of the gray kingbird, no positive identifications of wildlife encountered were made.

Quebradas Arenas

The Quebradas Arenas is a small stream no more than three feet wide and several inches in depth. Stream substrate varies and consists mostly of coarse/medium sand intermixed with gravel. Portions of the stream have been channelized presumably for storm water conveyance, and in some instances engineered banks consisting of riprap or other material are present. In general, vegetative communities and available habitats are representative of disturbed conditions. Riparian vegetation is primarily herbaceous; however, some shrubby species such as mamoncillo (*Melicoccus bijugatus*) were observed. Dense stands of kudzo (*Pueraria* spp.) were observed throughout the area. Other species included Mexican primrose-willow (*Ludwigia octovalvis*), minnieroot (*Ruellia tuberose*) and arrowhead vine (*Syngonium auritum*). Papaya (*Carica papaya*) and banana/plantain (*Musa* spp.) fields are also nearby. No wildlife was observed.

2.1.5 Threatened, Endangered Species/Sensitive Environments

Information regarding threatened and endangered species and ecologically sensitive environments that may exist at or in the vicinity of the site was requested from the EPA and PRDNER. Letters received from both agencies are presented in Appendix A.

2.1.5.1 Federally-Listed Species

The EPA reported that a review of United States Fish and Wildlife Service (USFWS) records indicated that five federally-listed species can be found within the municipality of Maunabo. These species include four coastal species, the green sea turtle (*Chelonia mydas*), leatherback sea turtle (*Dermochelys coriacea*), hawksbill sea turtle (*Eretmochelys imbricate*), and the West Indian manatee (*Trichechus manatus manatus*). Since the site is located more than 0.5 miles from the coast no impacts to these species are anticipated. The fifth species is Guajon or Puerto Rican Demon (*Eleutherodactylus cooki*). Review of critical habitats maps in relation to the project area indicated that this species is not in close proximity to the site.

2.1.5.2 Puerto Rico-Listed Species

The PRDNER reported that a review of their records for the site and surrounding area indicated no known occurrences of listed rare, threatened, and/or endangered species.

2.2 Conceptual Site Model

The CSM depicts the fate and transport of chemicals from source(s) to exposure media (surface water, sediment, soil, food, etc) and illustrates the exposure routes for ecological receptors. Development of the CSM includes identification of the sources of contamination, and potential exposure pathways (Figure 2-1).

2.2.1 Sources of Contamination

Sources of contamination have yet to be identified for the site. However, for the purposes of this SLERA, the source of contamination will consist of chemicals present in surface and subsurface soils, the result of historic spills and releases that have occurred on site resulting in the contamination of groundwater. Contamination originating from these sources may have, or continues, to migrate to surrounding areas via erosion, overland flow, and groundwater discharging to surface water.

2.2.2 Exposure Pathways

An exposure pathway is the means by which contaminants are transported from a source to ecological receptors. For this SLERA, contaminated soils represent the source of site-related contaminants such as PCE and DCE (Section 2.1.2). Any soil transport via erosion and groundwater discharge that occurs may result in the transport of contaminants to surrounding areas including the Rio Maunabo and Quebrada Arenas. The potential exposure pathways are illustrated on the CSM (Figure 2-1).

In undeveloped portions of the study area, habitats may support a number of terrestrial and aquatic species including invertebrates, fish, amphibians, reptiles, birds, and mammals. Ecological receptors utilizing these areas may be exposed to contaminated media via direct contact or incidental ingestion. Exposure of higher trophic-level receptors can also occur through food chain exposure (via ingestion of prey that may have become contaminated through site-related exposure).

2.3 Assessment Endpoints

Assessment endpoints are explicit expressions of an environmental resource that is considered of value, operationally defined by an ecological entity and its attributes (EPA 1997). In SLERAs, assessment endpoints are usually considered to be any adverse effects from site contaminants to any ecological receptors at the site. It is not practical or possible to directly evaluate risks to all the individual components of the ecosystem on site, so assessment endpoints are used to focus on particular components that could be adversely affected by the chemicals associated with the site.

A review of the CSM provided information for the selection of assessment endpoints. Within the study area, both terrestrial and aquatic ecosystems are present and have been potentially contaminated. It is expected that within these ecosystems a number of biotic communities inhabit and/or forage within these areas. Therefore, the assessment endpoints collectively focused on these groups.

Assessment endpoints evaluated in this SLERA include:

- Assessment Endpoint 1: Viability (survival, growth, and reproduction) of terrestrial ecological receptors/communities.
- Assessment Endpoint 2: Viability (survival, growth, and reproduction) of aquatic ecological receptors/communities.

2.4 Risk Questions

Risk questions summarize important components of the problem formulation phase of the SLERA and are based on the assessment endpoints. Risk questions are directly related to the testable hypotheses that can be accepted or rejected using the results of the SLERA. Selected risk questions to be answered in this SLERA include:

- May ecological receptors be exposed to site-related chemicals present in site soil, sediment, surface water and/or sediment porewater?
- Where present, are concentrations of site-related chemicals in soil sufficient to cause adverse effects on the survival, growth, and /or reproduction of terrestrial organisms (including plants)?
- Where present, are concentrations of site-related chemicals in sediment sufficient to cause adverse effects on the survival, growth, and /or reproduction of aquatic organisms?
- Where present, are concentrations of site-related chemicals in surface water sufficient to cause adverse effects on the survival, growth, and /or reproduction of aquatic organisms?
- Where present, are concentrations of site-related chemicals in porewater sufficient to cause adverse effects on the survival, growth, and /or reproduction of aquatic organisms?

2.5 Measurement Endpoints

Measurement endpoints are chosen to link the existing site conditions to the goals established by the assessment endpoints and are useful for assessment endpoint evaluation. Measurement endpoints are quantitative expressions of observed or measured biological responses to contamination relevant to selected assessment endpoints. For a SLERA, ESLs are commonly used as measurement endpoints. For this SLERA, measurement endpoints are based on conservative ESLs from sources discussed in Section 4.1.

For this SLERA, the following assessment endpoints and measurement endpoints were selected to evaluate whether site-related contaminants pose a risk to ecological receptors:

- Assessment Endpoint 1: Viability (survival, growth, and reproduction) of terrestrial ecological receptors/communities

Measurement Endpoint: Evaluate the toxicity of contaminants in soil by comparing maximum detected concentrations to soil-specific ESLs

- Assessment Endpoint 2: Viability (survival, growth, and reproduction) of aquatic ecological receptor/communities

Measurement Endpoint: Evaluate the toxicity of sediment, surface water, and porewater by comparing maximum-detected concentrations to sediment- and surface water-specific ESLs.

2.6 Data Used in the Screening Level Ecological Risk Assessment

This SLERA evaluates exposure to chemicals through direct contact with site media. All data used in the SLERA was collected in support of the RI. For this SLERA, a single maximum value for each medium type evaluated was selected. This approach also included surface soil samples which were collected from two areas, the Former Sugar Mill (FSM) and Puerto Rico Beverage (PRB) areas. For the purposes of this SLERA, only surface soil samples, collected from the surface to a depth of 2 feet below surface ground are evaluated. Sediment samples were collected from the surface to a depth of 6 inches. Analytical results can be found in Appendix B.

Background sediment and surface water samples were collected as part of the RI (Figure 2-2); however, use of this data was not used in the identification of COPCs, but rather is provided for informational purposes only. No background soil or porewater samples were collected.

2.6.1 Surface Soil

A total of 12 surface soil samples, six from the FSM area and six from the PRB area are evaluated in this SLERA (Figure 2-3). Samples were analyzed for target compound list (TCL) volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides and polychlorinated biphenyls (PCBs), and target analyte list (TAL) inorganics including cyanide.

VOCs: Two VOCs, acetone and 2-butanone, were detected in one sample, PRB-SB-3, collected from the PRB area at concentrations of 31 micrograms per kilogram (µg/kg), and an estimated value of 5.2 J µg/kg, respectively. No other VOCs were detected in any other sample.

SVOCs: Several SVOCs, consisting mostly of polycyclic aromatic hydrocarbons (PAHs) were detected in soil samples. The most compounds detected, highest frequency of detection, and highest concentrations measured were in samples collected from the FSM area. However, concentrations of PAHs measured were relatively low (<140 µg/kg). No PAHS were detected in four of the six samples collected from the PRB area.

Pesticides/PCBs: No PCBs were detected in any sample. Several pesticides were detected between both areas. The most commonly occurring compounds were 4,4'-DDE and alpha-chlordane which were detected at concentrations ranging from 0.31 µg/kg to an estimated value of 5.7 J µg/kg, and estimated values of 0.19 NJ µg/kg to 4.0 NJ µg/k, respectively. Other pesticides detected in both areas included 4,4'-DDT, aldrin, dieldrin, endosulfan sulfate, gamma-chlordane, heptachlor, and heptachlor epoxide at maximum concentrations of 9.1 µg/kg, 0.84 µg/kg, 3.2 µg/kg, 0.44 NJ µg/kg, 5.6 µg/kg, 1.2 NJ µg/kg, and 1.5 J µg/kg, respectively.

Inorganics: Of the metals that comprise the TAL suite, most were detected in all samples; however, beryllium and selenium were not detected in any sample. Silver was only detected in three of the 12 samples. When comparing the two areas, the most and highest concentrations of metals detected, in general, were those from the FSM area; however, when evaluating each area separately, concentrations of metals were relatively consistent with one another.

2.6.2 Sediment

A total of seven sediment samples were collected from the Rio Maunabo during the RI; six are evaluated in this SLERA and the seventh (SD-01) was collected from a background area upstream of site boundaries (Figure 2-2). Samples were analyzed for TCL VOCs, SVOCs, pesticides and PCBs, and TAL inorganics including cyanide.

VOCs: No VOCs were detected in any sample.

SVOCs: The compound bis(2-ethylhexyl)phthalate was detected in one sample, SD-05 at an estimated concentration of 81 J µg/kg. No other SVOCs were detected in any sample.

Pesticides/PCBs: A total of five pesticides, 4,4'-DDT, 4,4'-DDD, 4,4'-DDE, beta-BHC, and methoxychlor were detected at estimated maximum concentrations of 0.55 J µg/kg, 0.31 J µg/kg, 0.30 J µg/kg, 0.014 J µg/kg, and 0.062 J µg/kg, respectively. With the exception of methoxychlor being detected in two samples, other pesticides were only detected in one sample.

In the background sample, the pesticides 4,4'-DDD, 4,4'-DDE, endosulfan I and heptachlor were detected at concentrations of 0.46 µg/kg, 0.64 µg/kg, 0.12 µg/kg and 0.19 µg/kg, respectively.

Aroclor 1254 was detected in one sample, SD-07, at an estimated concentration of 9.2 J µg/kg. No other PCBs were detected in any sample.

Inorganics: Eight metals, antimony, beryllium, cadmium, cyanide, mercury, selenium, silver, and thallium were not detected in any sample. The highest concentrations of most metals were detected at location SD-05; however, levels between all locations including the background were relatively similar.

2.6.3 Surface Water

A total of seven surface water samples were collected from the Rio Maunabo during the RI; six are evaluated in this SLERA as the seventh (SW-01) was collected from a background area upstream of site boundaries (Figure 2-2). Samples were analyzed for TCL VOCs, SVOCs, pesticides and PCBs, and TAL inorganics including cyanide.

VOCs: Three VOCs, bromodichloromethane, bromoform, and dibromochloromethane were detected at concentrations ranging from an estimated value of 0.38 J micrograms per liter (µg/L) to 1.0 µg/L, an estimated value of 0.43 J µg/L to 0.64 µg/L, and 0.57 µg/L to 1.3 µg/L, respectively. With the exception of bromoform which was not detected at location SW-07, all three compounds were detected in samples collected from locations SW-05 through SW-07; SW-06 had the highest concentrations detected. No other VOCs were detected in any other sample.

SVOCs: One SVOC, bis(2-ethylhexyl)phthalate, was detected in samples from locations SW-02, SW-04, and SW-07 at concentrations ranging from an estimated value of 1.1 J µg/L to 2.5 µg/L. No other SVOCs were detected in any other sample.

Pesticides/PCBs: No pesticides or PCBs were detected in any sample.

Inorganics: Fourteen metals, antimony, arsenic, beryllium, cadmium, chromium, cobalt, iron, lead, mercury, nickel, selenium, silver, thallium and vanadium, were not detected in any sample. Cyanide was only detected at one site location, SW-03 at an estimated concentration of 4.3 J µg/L; cyanide was also detected in the background sample at an estimated concentration of 2.9 J µg/L. In general, concentrations of the majority of metals were consistent between locations including the background.

2.6.4 Porewater

A total of five sediment porewater samples were collected from the Rio Maunabo during the RI (Figure 2-2). Samples were analyzed for TCL VOCs, SVOCs, pesticides and PCBs, and TAL inorganics including cyanide.

VOCs: No VOCs were detected in any sample.

SVOCs: One SVOC, dimethylphthalate was detected in two samples, PZ-3 and PZ-1, at concentrations of 2.9 µg/L and 3.0 µg/L, respectively. No other SVOCs were detected in any sample.

Pesticides/PCBs: No PCBs were detected in any sample. The pesticides delta-BHC and heptachlor were detected at estimated concentrations of 0.0039 J µg/L and 0.0049 NJ µg/L at locations PZ-1 and PZ-2, respectively. No other pesticides were detected in any other sample.

Inorganics: Nine metals, antimony, beryllium, cadmium, chromium, lead, mercury, selenium, silver, and thallium were not detected in any sample. Cyanide and arsenic were only detected at location PZ-

5 at estimated concentrations of 4.3 J µg/L and 0.28 J µg/L, respectively. Cobalt and nickel were only detected at location PZ-4 at estimated concentrations of 0.59 J µg/L and 0.26 J µg/L, respectively. In general, concentrations of the majority of metals were consistent between locations; however, the highest concentrations of all inorganics detected were found in samples collected from either location PZ-4 or PZ-5.

Section 3

Exposure Assessment

The objective of the exposure assessment is to determine the pathways and media through which ecological receptors may be exposed to site-related chemicals. Exposure scenarios are simplified descriptions of how potential receptors may come in contact with contaminants. Potential exposure pathways are dependent on habitats and receptors present on-site, the extent and magnitude of contamination, and environmental fate and transport of contaminants.

The study area consists of both aquatic and terrestrial environments. During the ecological reconnaissance, observations were made that indicated these areas most likely provide habitat for several terrestrial and aquatic species, including invertebrates, fish, reptiles, amphibians, birds, and mammals. Organisms or representative groups of organisms can be exposed to contaminants by direct contact and/or ingestion of contaminated media and/or prey. Although several potential exposure scenarios can be identified for ecological receptors, it is most appropriate to focus the assessment on critical exposure scenarios or those most likely to contribute to risk. Thus, this SLERA focuses on the direct contact exposure scenario.

Benthic and infaunal organisms inhabit the sediment and directly absorb contaminants through dermal contact with sediment particles, groundwater discharge to surface water and interstitial water, as well as through ingestion of contaminated food items and incidental ingestion of sediment. Direct contact with the whole sediment burden incorporates the contaminant fraction adsorbed to the solid phase as well as contaminants dissolved in the liquid interstitial phase.

The soil macroinvertebrate community is in constant association with soil and is therefore potentially exposed to contaminants through direct contact with the soil and soil interstitial water. Additional exposure may result from the ingestion of contaminated food items. Macroinvertebrates may also be indirectly affected by a reduction in ecosystem functions, such as nutrient cycling and energy transfer that are critical to growth and reproduction.

Terrestrial and riparian plant communities may potentially be exposed to contaminants through direct contact with soil, sediment, porewater, groundwater discharge, and surface water. Vegetation may also be indirectly affected by a reduction in ecosystem functions, such as nutrient cycling and energy transfer, which are critical to growth and reproduction. The presence of contaminated vegetation not only places plants at risk, but also affects organisms that utilize vegetation for food and habitat.

Mammals may also utilize the areas for food. Such mammals may feed on a variety of food items such as plants, insects, fish, and soil/sediment macroinvertebrates. Therefore, these mammals may potentially be exposed to contaminants through ingestion of contaminated food items. They may also be exposed through incidental ingestion of contaminated soil or sediment, or direct contact with contaminated sediment, soil, surface water, or groundwater discharge, or ingestion of surface water.

R2-0000771

Other organisms that inhabit the study area include a variety of birds. These birds may be piscivorous and feed on fish, insectivorous and feed on soil macroinvertebrates or other insects, or herbivorous and feed on plants. Therefore, these birds may potentially be exposed to contaminants through ingestion of contaminated food items. They may also be exposed through incidental ingestion of contaminated soil or sediment, direct contact with contaminated sediment, surface water, groundwater discharge, or soil, or ingestion of surface water.

Assessment and measurement endpoints were identified and focused collectively on organisms potentially utilizing aquatic and terrestrial habitats found on site. For the purpose of this SLERA, maximum concentrations of contaminants detected in soil, sediment, porewater, and surface water serve as exposure point concentrations and are evaluated via direct exposure. Chemical-specific and media-specific ESLs serve as the effect concentrations. The comparison of these two values is used to estimate risk.

Section 4

Effects Assessment

An effects assessment includes an evaluation of the available types and sources of effects data and presents media- and chemical-specific screening levels that serve as conservative effects concentrations for the SLERA. Effects data were limited to screening level or benchmark concentrations.

This section of the SLERA describes and provides the sources of effects data selected for use in this evaluation. As appropriate for a SLERA, effects data are limited to ESLs. Screening values from the following references were applied in a hierarchical fashion to the maximum site-specific chemical concentrations detected in soil, sediment, surface water, and porewater as follow:

Soil

- EPA Ecological Soil Screening Levels; lowest value used (2008, 2007a through 2007g, 2006a, 2005a through 2005g, and 2003a and 2003b)
- Oak Ridge National Laboratory, Preliminary Remediation Goals for Ecological Endpoints (1997)
- EPA Region 5 Resource Conservation and Recovery Act Ecological Screening Levels (2003c)

Sediment

- Ontario Ministry of the Environment Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario (Persaud et. al 1993)
- EPA Region 3 Biological Technical Assistance Group (BTAG) Freshwater Sediment Screening Benchmarks (2006b)

Surface Water and Porewater

- Puerto Rico Water Quality Standards Regulation, Aquatic Life Values (2010)
- EPA National Recommended Water Quality Criteria (2009)
- EPA Region 3 BTAG Freshwater Screening Benchmarks (2006b)

In this SLERA, the first set of benchmarks noted above for each medium were examined first to determine if a screening value was available for a particular chemical. If a value was available, it was utilized. If not, values from secondary sources were used in the order they are listed above. If a selected screening level was exceeded, or no screening level was located, chemicals were retained as COPCs.

Section 5

Risk Characterization

The risk characterization integrates information from the exposure and effects assessments and estimates risk to representative ecological receptors. This SLERA relies on the hazard quotient (HQ) approach, supplemented by site observations to assess ecological risks at the site.

5.1 Hazard Quotient Approach

Potential risks to ecological receptors are evaluated using the HQ approach. This process involves comparing chemical concentrations measured in site media to their respective ESLs. By nature these values are conservative, and in this way avoid the potential for underestimating risk. For this SLERA, the maximum exposure concentration for a specific chemical is compared to its respective ESL counterpart and is expressed as a ratio per the following formula:

$$\textit{Hazard Quotient} = \frac{\textit{Maximum Detected Concentration of a Chemical}}{\textit{ESL}}$$

If resultant HQs are greater than unity (1.0), risk is implied. A HQ less than one suggest there is a high degree of confidence that minimal risk exists, and therefore, is considered insignificant. Higher HQs are not necessarily indicative of more severe effects because of varying degrees of uncertainty in the ESLs used to calculate HQs, and due to differences in toxicity endpoints and measurement endpoints.

5.2 Identification of Chemicals of Potential Concern

Chemicals with maximum detected concentrations above their respective ESLs are identified as COPCs, as are detected chemicals for which ESLs could not be identified, unless otherwise noted below. No benchmarks are available for calcium, magnesium, potassium, and sodium. However, these elements are not considered in the evaluation of risk because they are ubiquitous, occur naturally in high concentrations, are essential nutrients, and are unlikely to pose risk. In addition, tissue concentrations of these elements are regulated by living organisms; even at relatively high levels of exposure, internal concentrations generally do not become sufficiently high to cause toxic effects. The HQs and identified COPCs, and the rationale for their selection, are presented below (Tables 5-1 through 5-4). Information on the fate, transport, and toxicity of contaminants identified as COPCs is presented in Appendix C.

Chemicals detected with maximum concentrations exceeding ESLs (HQs >1.0):

- **Soil** (Table 5-1) - Inorganics: cadmium, chromium, copper, lead, manganese, mercury, vanadium, and zinc
- **Sediment** (Table 5-2) - Inorganics: copper
- **Surface Water** (Table 5-3) - Inorganics: barium

- **Porewater** (Table 5-4) - Inorganics: aluminum, barium, and iron

Chemicals detected with no corresponding ESLs:

- **Soil** (Table 5-1) - SVOCs: carbazole

  Inorganics: aluminum and iron

- **Sediment** (Table 5-2) - Inorganics: aluminum, barium, and vanadium
- **Surface Water** (Table 5-3) - VOCs: bromodichloromethane and dibromochloromethane
- **Porewater** (Table 5-4) - SVOCs: dimethylphthalate

5.3 Refinement of Chemicals of Potential Concern

Risk from exposure to several chemicals was determined through a comparison of chemicals detected in site media to their respective ESLs. However, those chemicals for which risk was noted are not considered site-related. Based on review of the site background, VOCs, more specifically PCE and DCE are site-related (Section 2.1.2). In addition, certain chemicals retained as COPCs can be eliminated from further evaluation or discussion as they occur naturally in high concentrations or are normally considered a residue or by-product of analytical techniques.

No soil ESLs for aluminum and iron, and no sediment ESLs for aluminum were located. Both metals are commonly occurring elements and are major components of almost all inorganic soil particles. Concentrations of aluminum and iron typically range from 10,000 to 300,000 mg/kg (i.e., 1% to 30%) and 20,000 to 550,000 mg/kg (i.e., 0.2% to 55%), respectively (EPA 2003a; 2003b). Concentrations of both metals detected in their respective media were well within or below the range of expected natural concentrations. In addition, a search of the literature indicates that any toxicity associated with these metals is pH dependent. Aluminum is considered toxic when soil pH is less than 5.5; iron is considered toxic to plants at a pH of less than 5.0 or above 8.0 (EPA 2003a; 2003b). Soil pH ranged from 7.31 to 7.66, well within acceptable levels relevant to any associated toxicity. Based on this, iron and aluminum are excluded from further evaluation.

Finally, the chemicals dimethylphthalate and bis(2-ethylhexyl)phthalate were detected in porewater and soil, respectively. No screening value was available for dimethylphthalate, and bis(2-ethylhexyl)phthalate was detected in exceedance of its respective ESL; however, they are not retained as COPCs. In general, phthalates are viewed as common laboratory contaminants, and both are not considered site-related; thus, both are eliminated from further evaluation.

5.4 Risk Summary

This section of the SLERA discusses the potential ecological significance of the estimated risks and provides answers to risk questions identified in Section 2. Ecological significance considers the limitations and uncertainties (see Section 6) with the quantitative HQ risk estimates. An important first step to understand the results of this SLERA is to answer the risk questions initially presented in Section 2, Problem Formulation.

The following risk questions were identified as important to the SLERA. The results of the SLERA are used to respond to these questions and to help form conclusions. The risk questions and associated responses are presented below.

- *May ecological receptors be exposed to site-related chemicals present in site soil, sediment, surface water and/or sediment porewater?*

  Response: No. Site-related chemicals were not detected in any sample. Other chemicals consisting mostly of metals, PAHs, and pesticides were detected in site media (Appendix B).

- *Where present, are concentrations of site-related chemicals in soil sufficient to cause adverse effects on the survival, growth, and /or reproduction of terrestrial organisms (including plants)?*

  Response: No. Site-related chemicals were not detected in soil. Concentrations of several metals were in exceedance of their respective ESLs (Table 5-1).

- *Where present, are concentrations of site-related chemicals in sediment sufficient to cause adverse effects on the survival, growth, and /or reproduction of aquatic organisms?*

  Response: No. Site-related chemicals were not detected in sediment; however, the maximum concentration of copper was detected above its respective ESL (Table 5-2).

- *Where present, are concentrations of site-related chemicals in surface water sufficient to cause adverse effects on the survival, growth, and /or reproduction of aquatic organisms?*

  Response: No. Site-related chemicals were not detected in surface water; however, the maximum concentration of barium was detected above its respective ESL (Table 5-3).

- *Where present, are concentrations of site-related chemicals in porewater sufficient to cause adverse effects on the survival, growth, and /or reproduction of aquatic organisms?*

  Response: No. Site-related chemicals were not detected in porewater; however, maximum concentrations of aluminum, barium, and iron were detected above their respective ESLs (Table 5-4).

Section 6

Uncertainty Assessment

Potential risks due to contaminants in site media to ecological communities or populations at the site were evaluated by comparing maximum exposure concentrations to ESLs, an approach that provides the lowest level at which harmful effects would be predicted to occur. Some degree of uncertainty inherent in these comparisons is introduced during various steps in the evaluation. The sources of uncertainty are discussed below, as well as whether the assumptions used are likely to over- or under-represent ecological risks from contaminants at the site. In general, because this SLERA uses conservative assumptions, risks are likely overestimated.

The main sources of uncertainty include natural variability, error, and insufficient knowledge. Natural variability is an inherent characteristic of ecological systems, their stressors, and their combined behavior in the environment. Biotic and abiotic parameters in these systems may vary to such a degree that the exposure and response of similar assessment endpoints in the same system may differ temporally and spatially. Factors that contribute to temporal and spatial variability include differences in individual organism behavior (within and between species), changes in the weather or ambient temperature, unanticipated interference from other stressors, interactions with other species in the community, differences between microenvironments, and numerous other factors.

6.1 Problem Formulation

Sources of uncertainty within the problem formulation phase of the SLERA relate to the selection of assessment endpoints and assumptions within the CSM.

The selection of appropriate assessment endpoints to characterize risk is a critical step within the problem formulation of an ecological risk assessment. If an assessment endpoint is overlooked or not identified, environmental risk at the site will be underestimated. Within this SLERA, the selection of assessment endpoints was performed with the intent of being inclusive. However, given the complexity of the environment and the state of knowledge of organism interactions, it is possible that unique exposure pathways or assessment endpoints exist that were not acknowledged within the problem formulation. If additional pathways or assessment endpoints exist, risk may be underestimated.

The CSM presents the pathways by which contaminants are released from source areas to expose receptors. However, some exposure pathways are difficult to evaluate or cannot be quantitatively evaluated based on available information. Within this SLERA only the direct contact pathway was evaluated. Use of such a conservative endpoint may result in overestimating potential risk.

Potential receptors represent a variety of organisms with different feeding and behavioral strategies. For this SLERA, the evaluation optimizes exposure of receptors by assuming a significant portion of their life cycles is restricted to areas of contamination. For example, the assumption that ecological receptors spend a significant portion of their life cycles at the site or a particular area may be conservative.

6.2 Exposure Assessment

All exposure assessments have a degree of uncertainty due to necessary simplifications and assumptions, which must be made as part of the evaluation. Major sources of uncertainty in the exposure assessment are discussed below.

Concentrations used to represent exposure point concentrations and characterizations of the distributions of COPCs can be a source of uncertainty. These issues relate to the adequate characterization of the nature and extent of chemical contamination. It is assumed that sufficient samples have been collected from site media and appropriately analyzed to adequately describe the nature and extent of chemical contamination resulting from the release of site-related chemicals.

When potential levels of uncertainty could adversely affect the results of the assessment, conservative approaches are taken that may result in over-protection of sensitive receptors. Such an approach is prudent where uncertainties are high and is in line with regulatory guidance for conducting SLERAs. For example, maximum detected concentrations of COPCs are used to assess potential risk at the SLERA stage, and this approach likely overestimated the average concentrations to which receptors may be exposed.

In this risk assessment, it was assumed that COPCs in environmental media were 100 percent bioavailable. This is a conservative assumption that most often will overestimate risk. Bioavailability can be affected by factors including chemical speciation, sorption onto soils or sediment, complexation, aging, competition with environmental ligands, or precipitation in anoxic environments in the presence of sulfides (Chapman et al. 2003). Soil and sediment particle size can also influence exposure concentrations and bioavailability; soil/sediment comprised of fine particles will tend to have higher COPC concentrations than coarser textured ones due to the larger surface area and increased number of potential adsorption sites.

6.3 Effects Assessment

Uncertainties associated with the effects assessment relate to estimations of ESLs, the use of conservative assumptions, and the degree of interaction between site contaminants.

Not all ESLs have the same degree of confidence. For some COPCs, information on toxicity is limited or not available. Additionally, many ESLs were derived from laboratory animal studies that evaluated exposure to a single chemical under controlled conditions. Wildlife species using the site may be exposed to a mixture of COPCs under sometimes stressful environmental conditions, which may affect the toxic impact of a contaminant. Additionally, extrapolation of an ESL derived from populations or species different from those at the site may introduce error because of differences in pharmacokinetics or population and species variability. Further, where ESLs were statistically determined, they do not represent absolute thresholds; they are reflective of the experimental design. Finally, ESLs incorporate error contributed by the use of results from many studies incorporating different methods of sample collection, preparation, and analysis. These factors may result in over- or underestimating ecological risk.

Uncertainties can be introduced by use of unrealistic assumptions in the CSM. In SLERAs, conservative assumptions are generally made in light of the uncertainty associated with the risk assessment process. This minimizes the possibility of concluding that no risk is present when a threat actually does exist (e.g., minimizes false negatives). However, the accuracy with which risk was predicted is not known. The use of conservative assumptions likely overestimates potential risk.

There is also the potential of cumulative stress from exposure to additional stressors (e.g., habitat degradation); however, this was not evaluated in this SLERA. If other stressors exist at the site, and if the effects of those stressors and the effects of exposure to site-related contaminants are cumulative, ecological risks at the site may be underestimated.

6.4 Risk Characterization

By definition, uncertainties in risk characterization are influenced by uncertainties in the exposure assessment and effects assessment. The adequate sampling and analysis of study area soil, sediment, surface water, and porewater minimize the uncertainties in the exposure assessment of these media. Descriptions of the magnitude and distribution of COPCs at the site are considered to be generally representative of current conditions. Since only the maximum-detected concentrations are used at this stage of the ecological risk assessment, the range of exposure concentrations is less critical to the results of the SLERA.

Effects data can also contribute to overall uncertainty in risk characterization. Science and scientific investigations cannot prove any hypothesis beyond doubt. The scientific method is instead based on stating the hypotheses, testing the hypotheses, and either accepting or rejecting the hypotheses based on the weight-of-evidence provided by test data. Confidence in the ability of selected ESLs to assess ecological risks varies for each data value selected. While all ESLs used in this SLERA are associated with some degree of uncertainty, it is the general trend described by the comparisons between exposure concentrations and effects concentrations, and the overall confidence in such comparisons, that are most important. Available information suggests that the ESLs selected for use in this SLERA are generally similar to other ESLs, are commonly accepted for screening, and adequate for estimating risk using conservative assumptions.

Detected concentrations of COPCs may not be indicative of bioavailable concentrations. All contaminant data used in the assessment were based upon the total concentration of the chemical present, as opposed to the bioavailable fraction. Both metals and organic compounds may bind to soil and sediment, making them less available to ecological receptors, particularly higher trophic level receptors. Thus, risk may be overestimated in some cases.

Another potential source of uncertainty is the small amount of biological or ecological survey data to support this SLERA. The types of surveys needed to aid in the determination of cause and effect relationships, especially at the community or population level, are highly dependent on data quality and quantity. Such data, however, are not typically included in a SLERA. Observations based on a more general site visit/survey are used to qualitatively evaluate habitat quality, habitat use, presence of receptors, and observations of adverse impacts.

Finally, the risk characterization method itself can contribute to uncertainty. Hazard quotients depend on a single value for both exposure concentration and effects concentration. Selecting a single screening level, only after consulting multiple sources to ensure some degree of consistency, minimizes the uncertainty associated with any single value. Incorporating site observations into final conclusions also reduces the dependence on strict quantitative risk estimates that, in some cases, can be highly uncertain.

Section 7

Summary and Conclusions

Based on a comparison of maximum detected concentrations of contaminants in site soil, sediment, surface water, and porewater to conservatively derived ESLs, the potential for ecological risk may occur. Specifically, HQs > 1.0 were calculated, which indicate potential risk from exposure to the following media-specific contaminants:

- **Soil:** cadmium, chromium, copper, lead, manganese, mercury, vanadium, and zinc
- **Sediment:** copper
- **Surface water:** barium
- **Porewater:** aluminum, barium, and iron

Potential risk from the following media-specific contaminants cannot be concluded as ESLs are not available for these compounds:

- **Soil:** carbazole
- **Sediment:** barium and vanadium
- **Surface water:** bromodichloromethane and dibromochloromethane

Chemicals of potential concern retained via comparison to their respective media-specific ESLs were all comprised of metals. The remaining COPCs, which included the organic compounds carbazole, bromodichloromethane, and dibromochloromethane were all retained as COPCs due to a lack of media-specific ESLs. No site-related chemicals (e.g., PCE and DCE) were detected in any media evaluated in this SLERA. Those metals detected above conservative ESLs are most likely reflective of natural conditions, or non site-related sources. Therefore, the site poses no site-related risk to ecological communities present.

Section 8
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Table 5-1
Comparison of Chemicals Detected in Soil to Ecological Screening Levels
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS Number	Minimum Concentration Detected	Maximum Concentration Detected	Location of Maximum Concentration	Frequency of Detection	Screening Value		Hazard Quotient	COPC	Rationale
Volatile Organic Compounds (µg/kg)										
Acetone	67-64-1	31	31	PRB-SB-3	1 / 12	2500	c	0.0124	No	BSL; LC
2-Butanone	78-93-3	5.2 J	5.2 J	PRB-SB-3	1 / 12	89600	c	0.0001	No	BSL; LC
Semi-volatile Organic Compounds (µg/kg)										
2-Methylnaphthalene	91-57-6	14 J	14 J	FSM-SB-3	1 / 12	3240	c	0.004	No	BSL
3-Nitroaniline	99-09-2	54 J	54 J	PRB-SB-1	1 / 12	3160	c	0.017	No	BSL
Acenaphthylene	208-96-8	11 J	13 J	FSM-SB-3	2 / 12	29000	a	0.0004	No	BSL
Anthracene	120-12-7	5.3 J	5.3 J	FSM-SB-3	1 / 12	29000	a	0.0002	No	BSL
Benzo(a)anthracene	56-55-3	3.9 J	78 J	FSM-SB-3	5 / 12	1100	a	0.071	No	BSL
Benzo(a)pyrene	50-32-8	4.4 J	76 J	FSM-SB-3	5 / 12	1100	a	0.069	No	BSL
Benzo(b)fluoranthene	205-99-2	4.4 J	89 J	FSM-SB-3	5 / 12	1100		0.081	No	BSL
Benzo(g,h,i)perylene	191-24-2	4.0 J	56 J	FSM-SB-3	6 / 12	1100	a	0.051	No	BSL
Benzo(k)fluoranthene	207-08-9	5.5 J	64 J	FSM-SB-3	4 / 12	1100		0.058	No	BSL
Bis(2-ethylhexyl)phthalate	117-81-7	1100	1100	PRB-SB-5	1 / 12	925	c	1.2	No	LC
Butylbenzylphthalate	85-68-7	13 J	200	PRB-SB-5	9 / 12	239	c	0.84	No	BSL; LC
Carbazole	86-74-8	4.2 J	4.2 J	FSM-SB-3	1 / 12	NL		NC	Yes	NV
Chrysene	218-01-9	4.6 J	96 J	FSM-SB-3	6 / 12	1100	a	0.09	No	BSL
Dibenzo(a,h)anthracene	53-70-3	12 J	18 J	FSM-SB-3	2 / 12	1100	a	0.02	No	BSL
Fluoranthene	206-44-0	4.8 J	130	FSM-SB-3	5 / 12	1100	a	0.12	No	BSL
Indeno(1,2,3-cd)Pyrene	193-39-5	4.0 J	62 J	FSM-SB-3	5 / 12	1100	a	0.06	No	BSL
Naphthalene	91-20-3	12 J	12 J	FSM-SB-3	1 / 12	29000	a	0.0004	No	BSL
Phenanthrene	85-01-8	5.5 J	81 J	FSM-SB-3	4 / 12	29000	a	0.0028	No	BSL
Pyrene	129-00-0	5.2 J	140	FSM-SB-3	6 / 12	1100	a	0.13	No	BSL
Pesticides (µg/kg)										
4,4'-DDE	72-55-9	0.31	5.7 J	FSM-SB-3	3 / 12	21	a	0.27	No	BSL
4,4'-DDT	50-29-3	0.98 J	9.1	FSM-SB-3	2 / 12	21	a	0.43	No	BSL
Aldrin	309-00-2	0.84	0.84	FSM-SB-2	1 / 12	3.31	c	0.25	No	BSL
alpha-Chlordane	5103-71-9	0.19 NJ	4.0 NJ	PRB-SB-5	2 / 12	224	c*	0.02	No	BSL
Dieldrin	60-57-1	0.20	3.2	FSM-SB-2	2 / 12	4.9	a	0.65	No	BSL
Endosulfan Sulfate	1031-07-8	0.44 NJ	0.44 NJ	FSM-SB-6	1 / 12	35.8	c	0.01	No	BSL
gamma-Chlordane	5103-74-2	0.52	5.6	PRB-SB-5	3 / 12	224	c*	0.03	No	BSL
Heptachlor	76-44-8	1.2 NJ	1.2 NJ	PRB-SB-5	1 / 12	5.98	c	0.20	No	BSL
Heptachlor Epoxide	1024-57-3	0.16 J	1.5 J	PRB-SB-5	2 / 12	152	c	0.01	No	BSL
Inorganics (mg/kg)										
Aluminum	7429-90-5	5140	15800	FSM-SB-4	12 / 12	NL		NC	No	CE
Antimony	7440-36-0	0.013 J	0.14 J	FSM-SB-2	5 / 12	0.27	a	0.52	No	BSL
Arsenic	7440-38-2	0.43 J	4.6	FSM-SB-3	8 / 12	18	a	0.26	No	BSL
Barium	7440-39-3	53.5	192	FSM-SB-4	12 / 12	330	a	0.58	No	BSL
Cadmium	7440-43-9	0.13 J	2.5	FSM-SB-4	8 / 12	0.36	a	6.9	Yes	ASL
Calcium	7440-70-2	868	65200	FSM-SB-5	12 / 12	NL		NC	No	EN
Chromium	7440-47-3	1.6	27.5	PRB-SB-5	12 / 12	26	a**	1.1	Yes	ASL

Table 5-1
Comparison of Chemicals Detected in Soil to Ecological Screening Levels
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS Number	Minimum Concentration Detected	Maximum Concentration Detected	Location of Maximum Concentration	Frequency of Detection	Screening Value		Hazard Quotient	COPC	Rationale
Cobalt	7440-48-4	2.1 J	10.5	FSM-SB-4	12 / 12	20	b	0.53	No	BSL
Copper	7440-50-8	22.2	107	PRB-SB-5	12 / 12	28	a	3.8	Yes	ASL
Cyanide	57-12-5	0.088 J	0.37 J	FSM-SB-1	10 / 12	1.3	c	0.28	No	BSL
Iron	7439-89-6	16400	41800	FSM-SB-4	12 / 12	NL		NC	No	CE
Lead	7439-92-1	2.2	710	FSM-SB-4	8 / 12	11	a	64.5	Yes	ASL
Magnesium	7439-95-4	1610	3610	FSM-SB-4	12 / 12	NL		NC	No	EN
Manganese	7439-96-5	135	547	FSM-SB-4	12 / 12	220	a	2.5	Yes	ASL
Mercury	7439-97-6	0.026 J	0.90	PRB-SB-5	12 / 12	0.00051	b	1765	Yes	ASL
Nickel	7440-02-0	0.32 J	19.2	FSM-SB-4	12 / 12	38	a	0.51	No	BSL
Potassium	7440-09-7	560 J	1650	FSM-SB-4	12 / 12	NL		NC	No	EN
Silver	7440-22-4	0.92 J	3.5	FSM-SB-4	3 / 12	4.2	a	0.83	No	BSL
Sodium	7440-23-5	105 J	361 J	PRB-SB-1	12 / 12	NL		NC	No	EN
Thallium	7440-28-0	0.0094 J	0.050 J	FSM-SB-3	12 / 12	1	b	0.05	No	BSL
Vanadium	7440-62-2	24.3	71.8	PRB-SB-3	12 / 12	7.8	a	9.2	Yes	ASL
Zinc	7440-66-6	27.4	742	FSM-SB-4	12 / 12	46	a	16.1	Yes	ASL

Notes:

µg/kg - micrograms per kilogram
mg/kg - milligrams per kilogram
ASL - above screening level
BSL - below screening level
CE- common earth element
COPC - chemical of potential concern
EN - essential nutrient
J - estimated
LC - laboratory contaminant
NC - no hazard quotient calculated
NJ - estimated;tentatively identified
NL - not listed
NV - chemical detected, but no screening value located
* - value for chlordane
** - value for trivalent chromium
a - United States Environmental Protection Agency (EPA) Ecological Soil Screening Levels. http://www.epa.gov/ecotox/ecossl/
b - Efroymson, R.A., G.W. Suter II, B.E. Sample, and D.S. Jones. 1997. Preliminary Remediation Goals for Ecological Endpoints.
Prepared for the U.S. Department of Energy, Office of Environmental Management Contract No. DE-AC05-84OR21401.
c - EPA. 2003. EPA Region 5 Resource Conservation and Recovery Act Ecological Screening Levels.

Table 5-2
Comparison of Chemicals Detected in Sediment to Ecological Screening Levels
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS Number	Minimum Concentration Detected	Maximum Concentration Detected	Location of Maximum Concentration	Frequency of Detection	Screening Value	Hazard Quotient	COPC	Rationale
Semi-volatile Organic Compounds (µg/kg)									
Bis(2-Ethylhexyl)Phthalate	117-81-7	81 J	81 J	SD-05	1 / 6	180 b	0.45	No	BSL; LC
Pesticides/PCBs (µg/kg)									
4,4'-DDT	50-29-3	0.55 J	0.55 J	SD-05	1 / 6	8 a	0.07	No	BSL
4,4'-DDD	72-54-8	0.31 J	0.31 J	SD-05	1 / 6	8 a	0.04	No	BSL
4,4'-DDE	72-55-9	0.30 J	0.30 J	SD-05	1 / 6	5 a	0.06	No	BSL
Beta-BHC	319-85-7	0.014 J	0.014 J	SD-03	1 / 6	5 a	0.003	No	BSL
Methoxychlor	72-43-5	0.051 J	0.062 J	SD-03	2 / 6	18.7 b	0.003	No	BSL
Aroclor 1254	11097-69-1	9.2 J	9.2 J	SD-07	1 / 6	60 a	0.15	No	BSL
Inorganics (mg/kg)									
Aluminum	7429-90-5	2580 J	5350 J	SD-05	6 / 6	NL	NC	No	CE
Arsenic	7440-38-2	0.65	2.7	SD-04	2 / 6	6 a	0.45	No	BSL
Barium	7440-39-3	27.0	71.9	SD-05	6 / 6	NL	NC	Yes	NV
Calcium	7440-70-2	1040	1670	SD-05	6 / 6	NL	NC	No	EN
Chromium	7440-47-3	2.1 J	6.0 J	SD-05	6 / 6	26 a	0.23	No	BSL
Cobalt	7440-48-4	2.5	7.1	SD-05	6 / 6	50	0.14	No	BSL
Copper	7440-50-8	10.6	31.8	SD-05	6 / 6	16 a	2.0	Yes	ASL
Iron	7439-89-6	5220 J	13500 J	SD-05	6 / 6	20000 a	0.68	No	BSL
Lead	7439-92-1	0.60 J	2.1 J	SD-05	5 / 6	31 a	0.07	No	BSL
Magnesium	7439-95-4	794	1890	SD-05	6 / 6	NL	NC	No	EN
Manganese	7439-96-5	237	333	SD-02	6 / 6	460 a	0.72	No	BSL
Nickel	7440-02-0	0.63	2.9	SD-04	6 / 6	16 a	0.18	No	BSL
Potassium	7440-09-7	273 J	790	SD-03	6 / 6	NL	NC	No	EN
Vanadium	7440-62-2	33.5 J	70.6 J	SD-05	6 / 6	NL	NC	Yes	NV
Zinc	7440-66-6	11.9	36.1	SD-04	6 / 6	120 a	0.30	No	BSL

Notes:

µg/kg - micrograms per kilogram
mg/kg - milligrams per kilogram
ASL - above screening level
BSL - below screening level
CE - common earth element
COPC - chemical of potential concern
EN - essential nutrient
J - estimated
LC - laboratory contaminant
NC - no hazard quotient calculated
NL - not listed
NV - chemical detected, but no screening value located
a - Persaud, D., Jaagumagi, R., and Hayton, A. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. ISBN 0-7729-9248-7. Ontario Ministry of the Environment, Ottawa, Ontario. 23p.
b - United States Environmental Protection Agency, Region 3 Biological Technical Assistance Group. 2006. Freshwater Sediment Screening Benchmarks. August.

Table 5-3
Comparison of Chemicals Detected in Surface Water to Ecological Screening Levels
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rice

Chemical Name	CAS Number	Minimum Concentration Detected	Maximum Concentration Detected	Location of Maximum Concentration	Frequency of Detection	Screening Value	Hazard Quotient	COPC	Rationale
Volatile Organic Compounds (µg/L)									
Bromodichloromethane	75-27-4	0.38 J	1.0	SW-06	3 / 6	NL	NC	Yes	NV
Bromoform	75-25-2	0.43 J	0.64	SW-06	2 / 6	320 c	0.002	No	BSL
Dibromochloromethane	124-48-1	0.57	1.3	SW-06	3 / 6	NL	NC	Yes	NV
Semi-volatile Organic Compounds (µg/L)									
Bis(2-Ethylhexyl)Phthalate	117-81-7	1.1 J	2.5	SW-07	3 / 6	16 c	0.16	No	BSL; LC
Inorganics (µg/L)									
Aluminum	7429-90-5	27.4	41.3	SW-07	3 / 6	87 b	0.47	No	BSL
Barium	7440-39-3	34.4	50.5	SW-05	6 / 6	4 c	12.6	Yes	ASL
Calcium	7440-70-2	15800	24500	SW-05	6 / 6	NL	NC	No	EN
Copper	7440-50-8	2.1	3.3	SW-03	4 / 6	10.8 a*	0.31	No	BSL
Cyanide	57-12-5	4.3 J	4.3 J	SW-03	1 / 6	5.2 a	0.83	No	BSL
Magnesium	7439-95-4	7850	9650	SW-05	5 / 6	NL	NC	No	EN
Manganese	7439-96-5	1.8	44.8	SW-04	6 / 6	120 c	0.37	No	BSL
Potassium	7440-09-7	1240	2300	SW-05	6 / 6	NL	NC	No	EN
Sodium	7440-23-5	21300	1910000	SW-03	6 / 6	680,000 c	2.8	No	EN
Zinc	7440-66-6	0.52 J	3.8	SW-06	6 / 6	123.9 a*	0.03	No	BSL

Notes:

µg/L - micrograms per liter
ASL - above screening level
BSL - below screening level
COPC - chemical of potential concern
EN - essential nutrient
J - estimated
LC - laboratory contaminant
NC - no hazard quotient calculated
NL - not listed
NV - chemical detected, but no screening value located
* - value adjusted using location specific hardness
a - Puerto Rico Water Quality Standards Regulation, Aquatic Life Values. 2010. Commonwealth of Puerto Rico Office of the Governor Environmental Quality Board. March.
b - United States Environmental Protection Agency (EPA). 2009. Office of Water. National Recommended Water Quality Criteria.
c - EPA, Region 3 Biological Technical Assistance Group. 2006. Freshwater Screening Benchmarks. August.

Table 5-4
Comparison of Chemicals Detected in Porewater to Ecological Screening Levels
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS Number	Minimum Concentration Detected		Maximum Concentration Detected		Location of Maximum Concentration	Frequency of Detection	Screening Value		Hazard Quotient	COPC	Rationale
Semi-volatile Organic Compounds (µg/L)												
Dimethylphthalate	131-11-3	2.9		3.0		PZ-1	2 / 5	NL		NC	No	LC
Pesticides (µg/L)												
Delta-BHC	319-86-8	0.0039	J	0.0039	J	PZ-1	1 / 5	141	c	0.00003	No	BSL
Heptachlor	76-44-8	0.0048	NJ	0.0048	NJ	PZ-2	1 / 5	0.053	b	0.09	No	BSL
Inorganics (µg/L)												
Aluminum	7429-90-5	61.6	J	861	J	PZ-4	3 / 5	87	b	9.9	Yes	ASL
Arsenic	7440-38-2	0.28	J	0.28	J	PZ-5	1 / 5	150	b	0.002	No	BSL
Barium	7440-39-3	47.2	J	124	J	PZ-4	5 / 5	4	c	31	Yes	ASL
Calcium	7440-70-2	24900		29300		PZ-5	5 / 5	NL		NC	No	EN
Cobalt	7440-48-4	0.59	J	0.59	J	PZ-4	1 / 5	23	c	0.03	No	BSL
Copper	7440-50-8	1.0	J	4.8		PZ-4	5 / 5	28.4	a*	0.17	No	BSL
Cyanide	57-12-5	4.3	J	4.3	J	PZ-5	1 / 5	5.2	a	0.83	No	BSL
Iron	7439-89-6	61.0	J	1060		PZ-4	3 / 5	1000	b	1.1	Yes	ASL
Magnesium	7439-95-4	9730		21700		PZ-4	5 / 5	NL		NC	No	EN
Manganese	7439-96-5	0.49	J	53.8		PZ-4	5 / 5	120	c	0.45	No	BSL
Nickel	7440-02-0	0.26	J	0.26	J	PZ-4	1 / 5	131.7	a*	0.002	No	BSL
Potassium	7440-09-7	1290		1990		PZ-5	5 / 5	NL		NC	No	EN
Sodium	7440-23-5	25600		30400		PZ-5	5 / 5	680000	c	0.04	No	EN
Vanadium	7440-62-2	2.1	J	5.2		PZ-4	5 / 5	20	c	0.26	No	BSL
Zinc	7440-66-6	1.3	J	4.3	J	PZ-4	5 / 5	267.1	a*	0.02	No	BSL

Notes:

µg/L - micrograms per liter
ASL - above screening level
BSL - below screening level
COPC - chemical of potential concern
EN - essential nutrient
J - estimated
LC - laboratory contaminant
NC - no hazard quotient calculated
NJ - estimated;tentatively identified
NL - not listed
NV - chemical detected, but no screening value located
* - value adjusted using location specific hardness
a - Puerto Rico Water Quality Standards Regulation, Aquatic Life Values. 2010. Commonwealth of Puerto Rico Office of the Governor Environmental Quality Board. March.
b - United States Environmental Protection Agency (EPA). 2009. Office of Water. National Recommended Water Quality Criteria.
c - EPA, Region 3 Biological Technical Assistance Group. 2006. Freshwater Screening Benchmarks. August.

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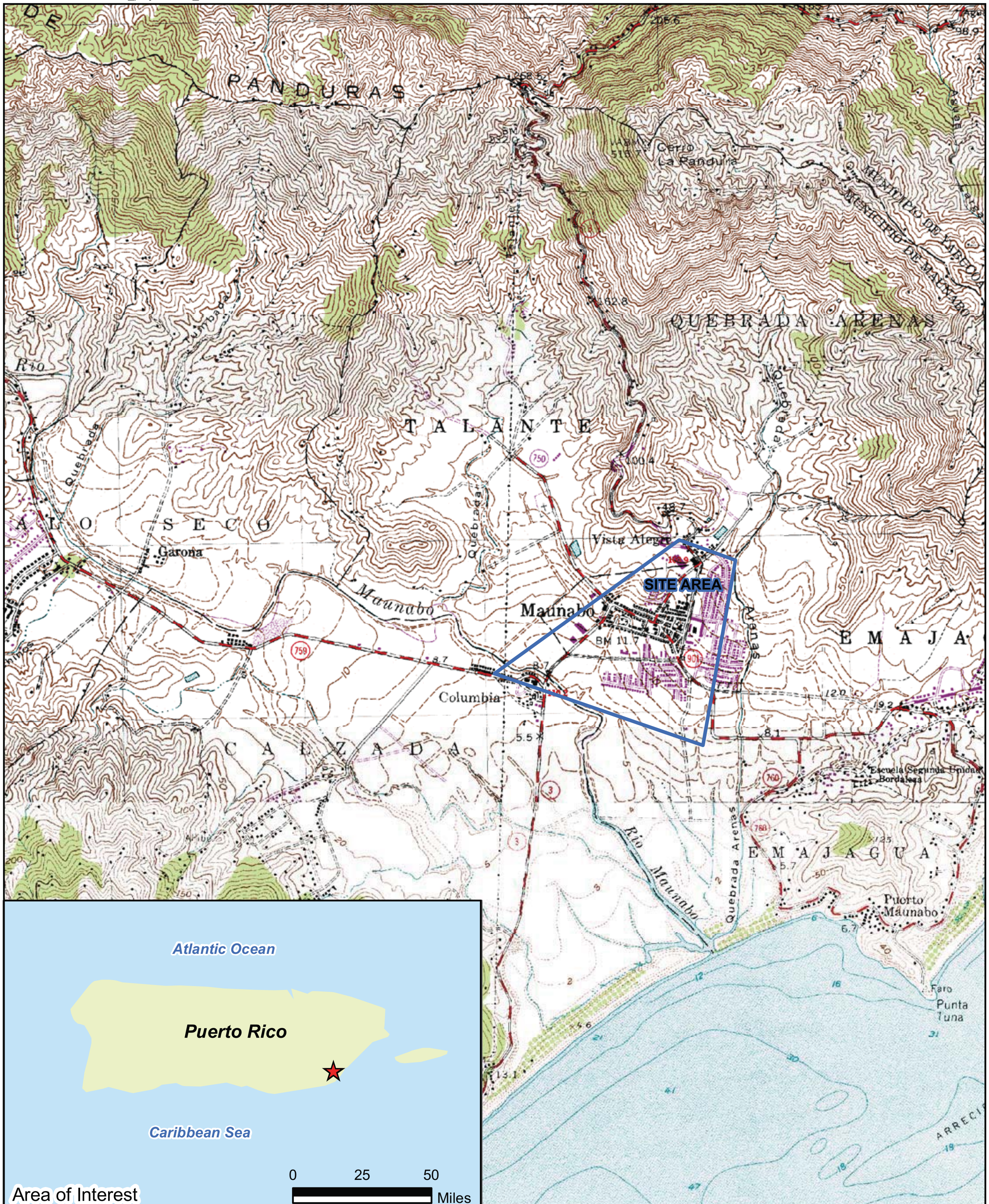


Source: USGS 7.5 Minute Series Topographic Quadrangle: Yabucoa, PR and Punta Tuna, PR.

N

0 2,500 Feet

Figure 1-1
Site Location Map
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

CDM Smith

R2-0000789

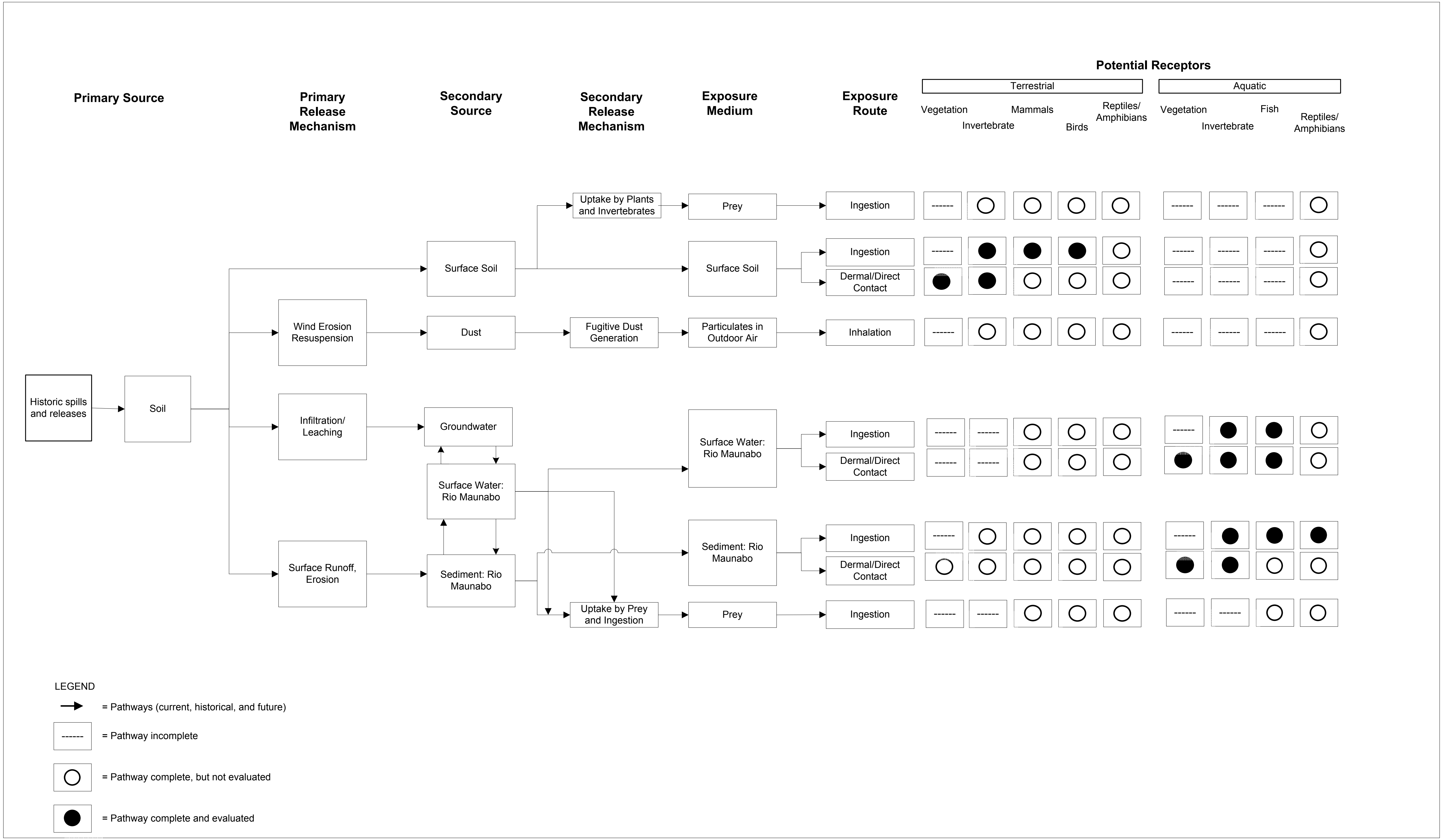


Figure 2-1
Conceptual Site Model
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

R2-0000790

Legend

Maunabo #1 Public Supply Wells

SW/SD-01 Surface Water/Sediment Sample

PZ-1 Porewater Sample

0 125 250 500 750 1,000 Feet

Figure 2-2
Surface Water, Porewater and Sediment Sample Locations
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

R2-0000791

Figure 2-3
Soil Sample Locations
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

R2-0000792

Appendix A

Letters from the United States Environmental Protection Agency and Puerto Rico Department of Natural and Environmental Resources

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 2
290 BROADWAY
NEW YORK, NY 10007-1866

JUL 07 2011

RECEIVED
JUL 11 2011
CAMP, DRESSER & McKEE
EDISON, NEW JERSEY

George G. Molnar
Environmental Scientist
CDM Federal
1110 Fieldcrest Avenue, 6th Floor
Edison, New Jersey 08837

Dear Mr. Molnar:

I have received your request for information concerning Federally-listed endangered or threatened species or critical habitats located on or in the vicinity of the Maunabo Groundwater Contamination Superfund site, located in Maunabo Municipality, Maunabo, Puerto Rico. This information is needed in support of a screening level ecological risk assessment which is currently underway for this project.

This site consists of a ground water plume with no identified source(s) of contamination, located in the southeastern part of the island (see Figure 1). The exact size of the plume of contamination, which includes tetrachloroethene (PCE), trichloroethene (TCE) and cis-1,2-dichloroethene (DCE), has of yet not been determined.

Figure 1

The Environmental Protection Agency (EPA) has reviewed information on the FWS website to determine what, if any, impacts to Federally-listed endangered or threatened species or critical habitats are possible as a result of the implementation of this proposed project. Written consultation is necessary if EPA determines that the proposed project may affect federally-listed species.

According to the US Fish & Wildlife's 2007 "Caribbean Endangered Species Map," 6 federally-listed threatened and endangered species can be found within the Maunabo municipio. These species include four coastal species, the green sea turtle (*Chelonia mydas*), the leatherback sea turtle (*Dermochelys coriacea*), the hawksbill sea turtle (Eretmochelys imbricata), the Brown pelican (*Pelecanus occidentalis*) and the West Indian manatee (*Trichechus manatus manatus*). As the project area for the Maunabo Groundwater Contamination site is located more than 0.5 miles from the coast, no impacts to these species are anticipated In addition, since the publication of this document, the Brown pelican has been determined to be recovered, and was delisted in 2009. The final species listed for Maunabo county is Guajon (*Eleutherodactylus cooki*), which is known to inhabit caves, grottoes, rocky formations and rocky streams within Manuabo municipio, including three distinct areas of designated critical habitat displayed on Figure 2. A look the designated critical habitat in relation to the project area clearly indicates that they are not in proximity to the site. Nevertheless, as this project moves forward, potential habitat of the Puerto Rican rock frog in the project area should be noted. It is possible that a survey for this species and its habitat may be needed during the RI/FS phase of this project. If it becomes likely that the Guajon may be impacted by remedial activities, we will initiate formal consultation for this project.

For your information, we have enclosed 2 documents, the 2004 "Recovery Plan for the Guajon or Puerto Rican Demon (*Eleutherodactylus cooki*)," and the October, 2007 Final Rule "Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Guajon (*Eleutherodactylus cooki*).

Please note that should the scope of future investigations or cleanups associated with this site go beyond the approximate boundaries of Figure 1, or should additional species be listed under the Endangered Species Act, a revised determination from this office will be needed.

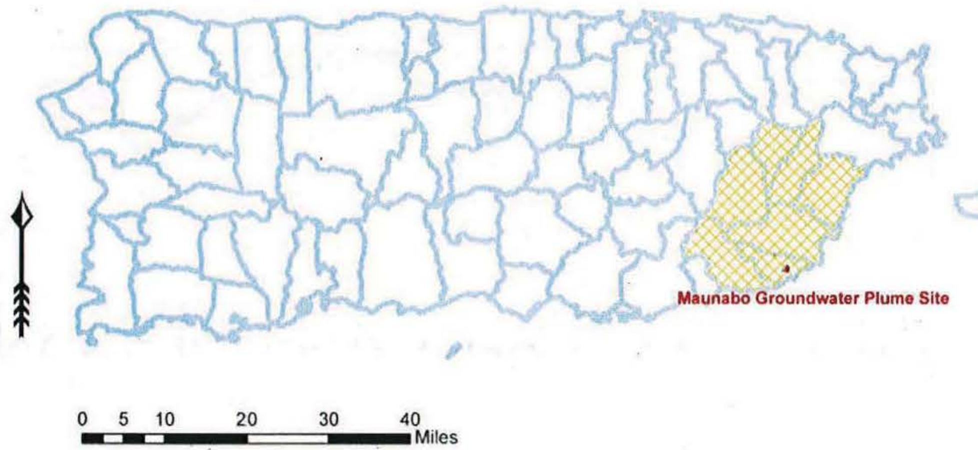
If you require additional information, please feel free to contact me at (212)-637-3759, or by email at ferreira.steve@epa.gov.

Sincerely,

Steven J. Ferreira
Environmental Scientist
Environmental Review Section

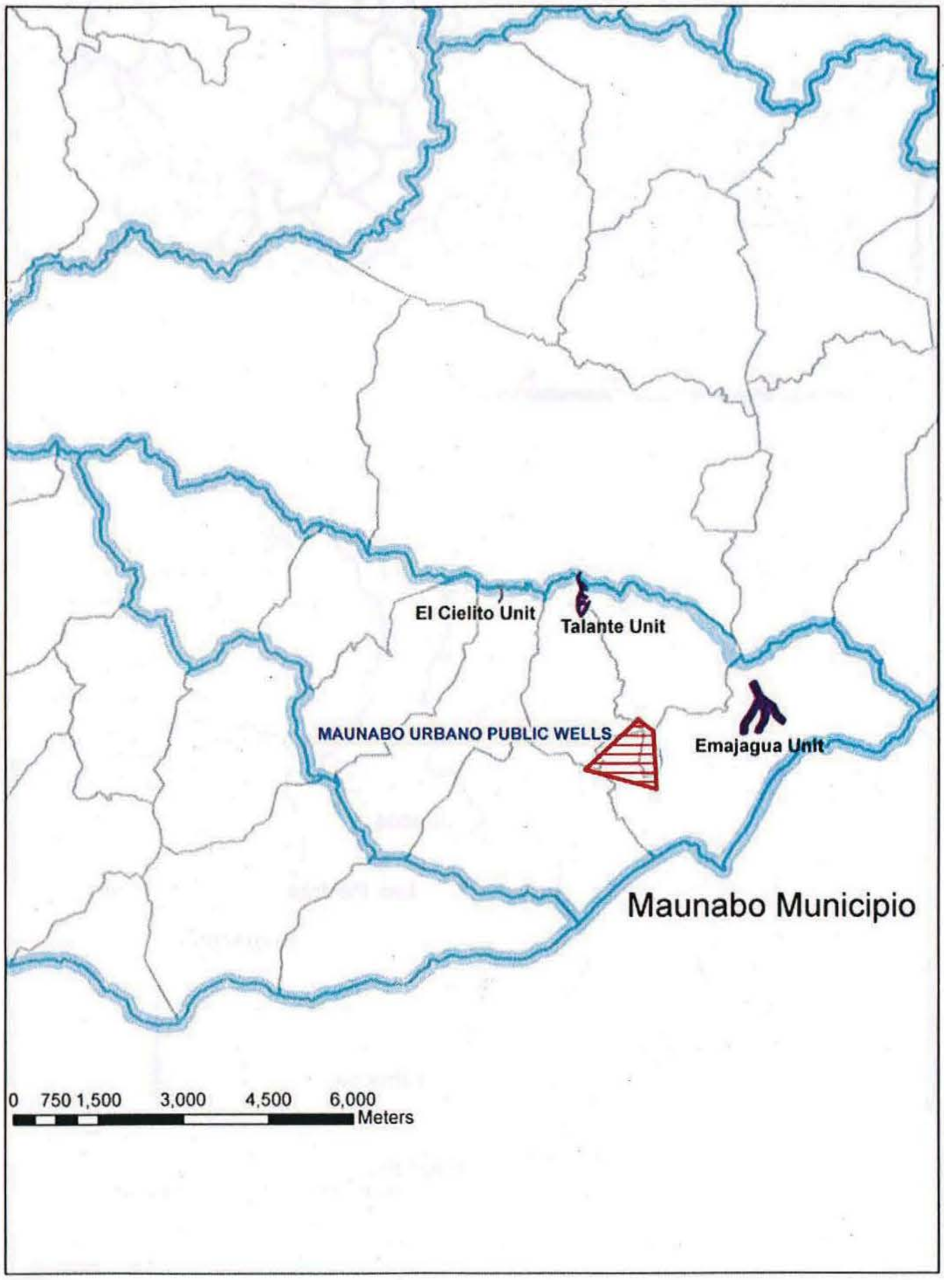
Enclosure

Figure 1: Range of Puerto Rican Rock Frog



http://www.fws.gov/caribbean/es/PDF/Map.pdf

Figure 2
Designated Critical Habitat for the Guajon in Manuabo Municipio



GOVERNMENT OF PUERTO RICO
Department of Natural and Environmental Resources

June 1, 2011

RECEIVED
JUN 1 4 2011
CAMP, DRESSER & McKEE
EDISON, NEW JERSEY

George C. Molnar
Environmental Scientist
CDM Federal Programs Corporation
110 Fieldcrest Avenue, 6th Floor
Edison, New Jersey 08837

Project: **EPA Region 2 RAC 2 Contract No.: EP-W-09-002**
Work Assignment: 014-RICO-02WE

DOC CONTROL NO.: **3320-014-00821**

Subject: **Information Request, Threatened and Endangered Species**
Maunabo Groundwater Contamination Site
Remedial Investigation/Feasibility Study
Maunabo, Puerto Rico

Dear Mr. Molnar:

This is a response to your request of information dated April 22, 2011 with respect to the above mentioned subject. The information hereby provided has been obtained based on available data at present in the Natural Heritage Division Data Bank concerning possible presence of Puerto Rico Department of Natural and Environmental Resources-listed rare, threatened, and/or endangered species at the site of concern in Maunabo, Puerto Rico. The site is indicated on the enclosed United States Geological Survey topographic map.

No particular occurances of any inventoried critical element nor legally listed rare, threatened, and/or endangered species are recognized at the site as result of the search done.

Should you have any further questions, please contact Mr. Vicente Quevedo, Technical Advisor of our Comprehensive Planning Area at 787-999-2200, extension 2521.

Sincerely,

Héctor Rivera Santiago
Acting Assistant Secretary
Comprehensive Planning Area

enclosure

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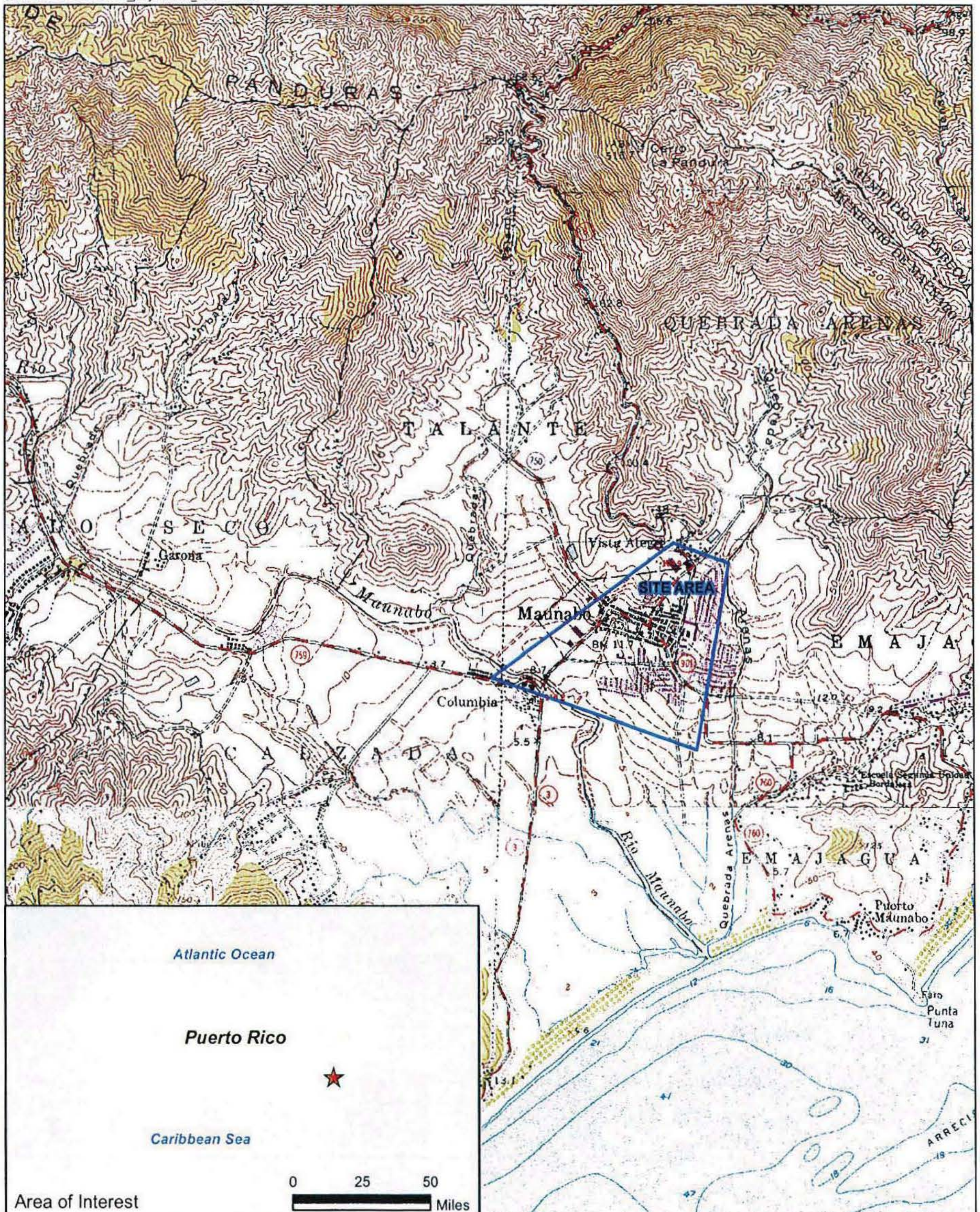

Source: USGS 7.5 Minute Series Topographic Quadrangle: Yabucoa, PR and Punta Tuna, PR.

N

Feet

0 2,500

CDM

Site Location Map
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Appendix B

Analytical Results

Appendix B
Surface Soil Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS No.	Location											
		FSM-SB-1	FSM-SB-2	FSM-SB-3	FSM-SB-4	FSM-SB-5	FSM-SB-6	PRB-SB-1	PRB-SB-2	PRB-SB-3	PRB-SB-4	PRB-SB-5	PRB-SB-6
Volatile Organic Compounds (µg/kg)													
1,1,1-Trichloroethane	71-55-6	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,1,2,2-Tetrachloroethane	79-34-5	3.3 U	2.8 U	3.3 U	3.1 U	3 U	2.7 U	3.3 U	2.8 U	2.7 U	2.7 U	3.6 U	2.9 U
1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,1,2-Trichloroethane	79-00-5	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,1-Dichloroethane	75-34-3	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,1-Dichloroethene	75-35-4	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,2,3-Trichlorobenzene	87-61-6	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,2,4-Trichlorobenzene	120-82-1	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,2-Dibromo-3-Chloropropane	96-12-8	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,2-Dibromoethane	106-93-4	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,2-Dichlorobenzene	95-50-1	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,2-Dichloroethane	107-06-2	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,2-Dichloropropane	78-87-5	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,3-Dichlorobenzene	541-73-1	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,3-Dichloropropylene	542-75-6	3.3 U	2.8 U	3.3 U	3.1 U	3 U	2.7 U	3.3 U	2.8 U	2.7 U	2.7 U	3.6 U	2.9 U
1,4-Dichlorobenzene	106-46-7	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
1,4-Dioxane	123-91-1	110 U	93 U	110 U	100 U	99 R	91 U	110 U	92 U	89 U	89 U	120 U	95 U
2-Butanone	78-93-3	11 U	9.3 U	11 U	10 U	9.9 U	9.1 U	11 U	9.2 U	5.2 J	8.9 U	12 U	9.5 U
2-Hexanone	591-78-6	11 U	9.3 U	11 U	10 U	9.9 U	9.1 U	11 U	9.2 U	8.9 U	8.9 U	12 U	9.5 U
4-Methyl-2-Pentanone	108-10-1	11 U	9.3 U	11 U	10 U	9.9 U	9.1 U	11 U	9.2 U	8.9 U	8.9 U	12 U	9.5 U
Acetone	67-64-1	11 U	9.3 U	11 U	10 U	9.9 U	9.1 U	11 U	9.2 U	31	8.9 U	12 U	9.5 U
Benzene	71-43-2	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Bromochloromethane	74-97-5	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Bromodichloromethane	75-27-4	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Bromoform	75-25-2	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Bromomethane	74-83-9	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Carbon Disulfide	75-15-0	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Carbon Tetrachloride	56-23-5	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Chlorobenzene	108-90-7	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Chloroethane	75-00-3	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Chloroform	67-66-3	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Chloromethane	74-87-3	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
cis-1,2-Dichloroethene	156-59-2	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
cis-1,3-Dichloropropene	10061-01-5	3.3 U	2.8 U	3.3 U	3.1 U	3 U	2.7 U	3.3 U	2.8 U	2.7 U	2.7 U	3.6 U	2.9 U
Cyclohexane	110-82-7	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Dibromochloromethane	124-48-1	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Dichlorodifluoromethane	75-71-8	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Ethylbenzene	100-41-4	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Isopropylbenzene	98-82-8	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
m,p-Xylene	179601-23-1	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Methyl Acetate	79-20-9	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Methyl Tert-Butyl Ether	1634-04-4	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Methylcyclohexane	108-87-2	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U

Appendix B
Surface Soil Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS No.	Location											
		FSM-SB-1	FSM-SB-2	FSM-SB-3	FSM-SB-4	FSM-SB-5	FSM-SB-6	PRB-SB-1	PRB-SB-2	PRB-SB-3	PRB-SB-4	PRB-SB-5	PRB-SB-6
Methylene Chloride	75-09-2	5.5 U	4.6 U	5.5 U	5.1 U	5 UJ	4.6 UJ	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
o-Xylene	95-47-6	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Styrene	100-42-5	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Tetrachloroethene	127-18-4	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Toluene	108-88-3	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
trans-1,2-Dichloroethene	156-60-5	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
trans-1,3-Dichloropropene	10061-02-6	3.3 U	2.8 U	3.3 U	3.1 U	3 U	2.7 U	3.3 U	2.8 U	2.7 U	2.7 U	3.6 U	2.9 U
Trichloroethene	79-01-6	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Trichlorofluoromethane	75-69-4	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Vinyl Chloride	75-01-4	5.5 U	4.6 U	5.5 U	5.1 U	5 U	4.6 U	5.5 U	4.6 U	4.5 U	4.5 U	6 U	4.8 U
Semi-volatile Organic Compounds (µg/kg)													
1,1'-Biphenyl	92-52-4	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
1,2,4,5-Tetrachlorobenzene	95-94-3	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
2,4,5-Trichlorophenol	95-95-4	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
2,4,6-Trichlorophenol	88-06-2	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
2,4-Dichlorophenol	120-83-2	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
2,4-Dimethylphenol	105-67-9	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
2,4-Dinitrophenol	51-28-5	190 U	190 U	190 U	200 U	190 U	180 U	180 U	180 U	190 U	180 U	220 U	190 U
2,4-Dinitrotoluene	121-14-2	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
2,4-Dinitrotoluene	121-14-2	1.9 U	1.9 U	1.9 U	2 UJ	1.9 U	1.8 U	1.8 U	1.8 U	1.9 U	1.8 U	2.2 U	1.9 U
2,6-Dinitrotoluene	606-20-2	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
2,6-Dinitrotoluene	606-20-2	1.9 U	1.9 U	1.9 U	2 U	1.9 U	1.8 U	1.8 U	1.8 U	1.9 U	1.8 U	2.2 U	1.9 U
2-Chloronaphthalene	91-58-7	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
2-Chlorophenol	95-57-8	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
2-Methylnaphthalene	91-57-6	96 U	96 U	14 J	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
2-Methylphenol	95-48-7	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
2-Nitroaniline	88-74-4	190 U	190 U	190 U	200 U	190 U	180 U	180 U	180 U	190 U	180 U	220 U	190 U
2-Nitrophenol	88-75-5	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
3,3'-Dichlorobenzidine	91-94-1	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
3,3'-Dichlorobenzidine	91-94-1	1.9 U	1.9 U	1.9 U	2 U	1.9 U	1.8 U	1.8 UJ	1.8 UJ	1.9 U	1.8 UJ	2.2 U	1.9 U
3-Nitroaniline	99-09-2	190 U	190 U	190 U	200 U	190 U	180 U	54 J	180 U	190 U	180 U	220 U	190 U
4,6-Dinitro-2-Methylphenol	534-52-1	190 U	190 U	190 U	200 U	190 U	180 U	180 U	180 U	190 U	180 U	220 U	190 U
4-Bromophenyl-Phenylether	101-55-3	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
4-Chloro-3-Methylphenol	59-50-7	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
4-Chloroaniline	106-47-8	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
4-Chlorophenyl-Phenylether	7005-72-3	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
4-Methylphenol	106-44-5	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
4-Nitroaniline	100-01-6	190 U	190 U	190 U	200 U	190 U	180 U	180 U	180 U	190 U	180 U	220 U	190 U
4-Nitrophenol	100-02-7	190 U	190 U	190 U	200 U	190 U	180 U	180 U	180 U	190 U	180 U	220 U	190 U
Acenaphthene	83-32-9	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U

Appendix B
Surface Soil Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS No.	Location											
		FSM-SB-1	FSM-SB-2	FSM-SB-3	FSM-SB-4	FSM-SB-5	FSM-SB-6	PRB-SB-1	PRB-SB-2	PRB-SB-3	PRB-SB-4	PRB-SB-5	PRB-SB-6
Acenaphthylene	208-96-8	96 U	96 U	13 J	100 U	98 U	11 J	92 U	95 U	96 U	95 U	120 U	96 U
Acetophenone	98-86-2	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Anthracene	120-12-7	96 U	96 U	5.3 J	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Atrazine	1912-24-9	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Benzaldehyde	100-52-7	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Benzo(a)anthracene	56-55-3	96 U	96 U	78 J	8.2 J	9.1 J	36 J	92 U	95 U	96 U	95 U	120 U	3.9 J
Benzo(a)pyrene	50-32-8	96 U	96 U	76 J	9.4 J	7.9 J	40 J	92 U	95 U	96 U	95 U	120 U	4.4 J
Benzo(b)fluoranthene	205-99-2	96 U	96 U	89 J	8.2 J	8.6 J	42 J	92 U	95 U	96 U	95 U	120 U	4.4 J
Benzo(g,h,i)perylene	191-24-2	96 U	8.3 J	56 J	6.8 J	6.3 J	34 J	92 U	95 U	96 U	95 U	120 U	4 J
Benzo(k)fluoranthene	207-08-9	96 U	96 U	64 J	7.6 J	5.5 J	35 J	92 U	95 U	96 U	95 U	120 U	96 U
bis(2-Chloroethoxy)Methane	111-91-1	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
bis(2-Chloroethyl) Ether	111-44-4	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
bis(2-Chloroethyl) Ether	111-44-4	1.9 U	1.9 U	1.9 U	2 U	1.9 U	1.8 U	1.8 U	1.8 U	1.9 U	1.8 U	2.2 U	1.9 U
bis(2-Ethylhexyl)Phthalate	117-81-7	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	1100	96 U
bis-Chloroisopropyl Ether	108-60-1	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Butylbenzylphthalate	85-68-7	13 J	14 J	74 J	21 J	45 J	120	92 U	65 J	96 U	95 U	200	39 J
Caprolactam	105-60-2	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Carbazole	86-74-8	96 U	96 U	4.2 J	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Chlorophenols	58-90-2	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Chrysene	218-01-9	96 U	96 U	96 J	10 J	15 J	49 J	92 U	95 U	96 U	95 U	6.4 J	4.6 J
Dibenzo(a,h)anthracene	53-70-3	96 U	96 U	18 J	100 U	98 U	12 J	92 U	95 U	96 U	95 U	120 U	96 U
Dibenzofuran	132-64-9	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Diethylphthalate	84-66-2	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Dimethylphthalate	131-11-3	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Di-n-Butylphthalate	84-74-2	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Di-n-Octylphthalate	117-84-0	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Fluoranthene	206-44-0	96 U	96 U	130	13 J	11 J	67 J	92 U	95 U	96 U	95 U	120 U	4.8 J
Fluorene	86-73-7	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Hexachlorobenzene	118-74-1	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Hexachlorobutadiene	87-68-3	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Hexachlorocyclopentadiene	77-47-4	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Hexachloroethane	67-72-1	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Indeno(1,2,3-cd)pyrene	193-39-5	96 U	96 U	62 J	7.7 J	7 J	34 J	92 U	95 U	96 U	95 U	120 U	4 J
Isophorone	78-59-1	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Naphthalene	91-20-3	96 U	96 U	12 J	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Nitrobenzene	98-95-3	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
N-Nitroso-Di-n-Propylamine	621-64-7	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
N-Nitroso-Di-n-Propylamine	621-64-7	1.9 U	1.9 U	1.9 U	2 U	1.9 U	1.8 U	1.8 U	1.8 U	1.9 U	1.8 U	2.2 U	1.9 U
N-Nitrosodiphenylamine	86-30-6	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Pentachlorophenol	87-86-5	190 U	190 U	190 U	200 U	190 U	180 U	180 U	180 U	190 U	180 U	220 U	190 U
Pentachlorophenol	87-86-5	3.7 U	3.7 U	3.8 U	4 U	3.8 U	3.6 U	3.6 U	3.7 U	3.7 U	3.7 U	4.5 U	3.7 UJ
Phenanthrene	85-01-8	96 U	96 U	81 J	5.5 J	7 J	37 J	92 U	95 U	96 U	95 U	120 U	96 U
Phenol	108-95-2	96 U	96 U	98 U	100 U	98 U	92 U	92 U	95 U	96 U	95 U	120 U	96 U
Pyrene	129-00-0	96 U	5.2 J	140	14 J	16 J	78 J	92 U	95 U	96 U	95 U	120 U	5.5 J

Appendix B
Surface Soil Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS No.	Location											
		FSM-SB-1	FSM-SB-2	FSM-SB-3	FSM-SB-4	FSM-SB-5	FSM-SB-6	PRB-SB-1	PRB-SB-2	PRB-SB-3	PRB-SB-4	PRB-SB-5	PRB-SB-6
Pesticides/PCBs (µg/kg)													
4,4'-DDD	72-54-8	0.19 U	0.19 U	0.19 U	0.2 U	0.19 U	0.18 U	0.18 U	0.18 U	0.19 U	0.18 U	2.9 R	0.19 U
4,4'-DDE	72-55-9	0.19 U	0.19 U	5.7 J	0.2 U	0.19 U	0.18 U	0.18 U	0.18 U	0.19 U	0.18 U	1.3 NJ	0.31
4,4'-DDT	50-29-3	0.19 U	0.19 U	9.1	0.2 U	0.19 U	0.18 U	0.18 U	0.18 U	0.19 U	0.18 U	0.98 J	0.19 U
Aldrin	309-00-2	0.096 U	0.84	0.098 U	0.1 U	0.098 U	0.092 U	0.092 U	0.095 U	0.096 U	0.095 U	0.12 UJ	0.096 U
alpha-BHC	319-84-6	0.096 U	0.096 U	0.098 U	0.1 U	0.098 U	0.092 U	0.092 U	0.095 U	0.096 U	0.095 U	0.12 UJ	0.096 U
alpha-Chlordane	5103-71-9	0.096 U	0.38 R	0.098 U	0.1 U	0.098 U	0.19 NJ	0.092 U	0.095 U	0.096 U	0.095 U	4 NJ	0.63 R
beta-BHC	319-85-7	0.096 U	0.096 U	0.098 U	0.1 U	0.098 U	0.092 U	0.092 U	0.095 U	0.096 U	0.095 U	0.12 UJ	0.096 U
delta-BHC	319-86-8	0.096 U	0.096 U	0.098 U	0.1 U	0.098 U	0.092 U	0.092 U	0.095 U	0.096 U	0.095 U	0.12 UJ	0.096 U
Dieldrin	60-57-1	0.19 U	3.2	0.19 U	0.2 U	0.19 U	0.2	0.18 U	0.18 U	0.19 U	0.18 U	0.22 UJ	0.19 U
Endosulfan I	959-98-8	0.096 U	0.096 U	0.098 U	0.1 U	0.098 U	0.092 U	0.092 U	0.095 U	0.096 U	0.095 U	0.12 UJ	0.096 U
Endosulfan II	33213-65-9	0.19 U	0.19 U	0.19 U	0.2 U	0.19 U	0.18 U	0.18 U	0.18 U	0.19 U	0.18 U	0.22 UJ	0.19 U
Endosulfan Sulfate	1031-07-8	0.19 U	0.19 U	0.19 U	0.2 U	0.19 U	0.44 NJ	0.18 U	0.18 U	0.19 U	0.18 U	0.22 UJ	0.19 U
Endrin	72-20-8	0.19 U	0.19 U	0.19 U	0.2 U	0.19 U	0.18 U	0.18 U	0.18 U	0.19 U	0.18 U	0.22 UJ	0.19 U
Endrin Aldehyde	7421-93-4	0.19 U	0.19 U	0.19 U	0.2 U	0.19 U	0.18 U	0.18 U	0.18 U	0.19 U	0.18 U	0.22 UJ	0.19 U
Endrin Ketone	53494-70-5	0.19 U	0.19 U	0.19 U	0.2 U	0.19 U	0.18 U	0.18 U	0.18 U	0.19 U	0.18 U	0.22 UJ	0.09 U
gamma-BHC (Lindane)	58-89-9	0.096 U	0.096 U	0.098 U	0.1 U	0.098 U	0.092 U	0.092 UJ	0.095 U	0.096 U	0.095 U	0.12 UJ	0.096 U
gamma-Chlordane	5103-74-2	0.096 U	0.52	0.098 U	0.1 U	0.098 U	0.092 U	0.092 U	0.095 U	0.096 U	0.095 U	5.6	1.4
Heptachlor	76-44-8	0.096 U	0.096 U	0.098 U	0.1 U	0.098 U	0.092 U	0.092 U	0.095 U	0.096 U	0.095 U	1.2 NJ	0.43 R
Heptachlor Epoxide	1024-57-3	0.096 U	0.096 U	0.098 U	0.1 U	0.098 U	0.092 U	0.092 U	0.095 U	0.096 U	0.095 U	1.5 J	0.16 J
Methoxychlor	72-43-5	0.96 U	0.96 U	0.98 U	1 U	0.98 U	0.92 U	0.92 U	0.95 U	0.96 U	0.95 U	1.2 UJ	0.96 U
Toxaphene	8001-35-2	9.6 U	9.6 U	9.8 U	10 U	9.8 U	9.2 U	9.2 U	9.5 U	9.6 U	9.5 U	12 UJ	9.6 U
Aroclor 1016	12674-11-2	37 U	37 U	38 U	40 U	38 U	36 U	36 U	37 U	37 U	37 U	45 U	37 U
Aroclor 1221	11104-28-2	37 U	37 U	38 U	40 U	38 U	36 U	36 U	37 U	37 U	37 U	45 U	37 U
Aroclor 1232	11141-16-5	37 U	37 U	38 U	40 U	38 U	36 U	36 U	37 U	37 U	37 U	45 U	37 U
Aroclor 1242	53469-21-9	37 U	37 U	38 U	40 U	38 U	36 U	36 U	37 U	37 U	37 U	45 U	37 U
Aroclor 1248	12672-29-6	37 U	37 U	38 U	40 U	38 U	36 U	36 U	37 U	37 U	37 U	45 U	37 U
Aroclor 1254	11097-69-1	37 U	37 U	38 U	40 U	38 U	36 U	36 U	37 U	37 U	37 U	45 U	37 U
Aroclor 1260	11096-82-5	37 U	37 U	38 U	40 U	38 U	36 U	36 U	37 U	37 U	37 U	45 U	37 U
Aroclor 1262	37324-23-5	37 U	37 U	38 U	40 U	38 U	36 U	36 U	37 U	37 U	37 U	45 U	37 U
Aroclor 1268	11100-14-4	37 U	37 U	38 U	40 U	38 U	36 U	36 U	37 U	37 U	37 U	45 U	37 U

Appendix B
Surface Soil Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS No.	Location											
		FSM-SB-1	FSM-SB-2	FSM-SB-3	FSM-SB-4	FSM-SB-5	FSM-SB-6	PRB-SB-1	PRB-SB-2	PRB-SB-3	PRB-SB-4	PRB-SB-5	PRB-SB-6
Inorganics (mg/kg)													
Aluminum	7429-90-5	8440	8200	11700	15800	13800	5140	9310	7930	15700	13100	8340	7060
Antimony	7440-36-0	0.016 J	0.14 J	0.13 J	0.032 R	0.077 R	0.046 J	0.015 R	0.016 R	0.0046 R	0.01 R	0.047 R	0.013 J
Arsenic	7440-38-2	0.84 J	2.9	4.6	1.7	3.2	2.1	1.1 U	1.1 U	1.1 U	1.1 U	2.9	0.43 J
Barium	7440-39-3	69.3	77.1	134	192	179	53.5	71.4	82.1	106	94.9	57.5	76.2
Beryllium	7440-41-7	0.56 U	0.58 U	0.58 U	0.61 U	0.6 U	0.53 U	0.54 U	0.56 U	0.57 U	0.57 U	0.66 U	0.57 U
Cadmium	7440-43-9	0.13 J	0.47 J	1.4	2.5	1.6	0.85	0.54 U	0.56 U	0.57 U	0.57 U	1.1	0.13 J
Calcium	7440-70-2	5890	26100	17300	9750	65200	2660	2420	868	2860	2140	2550	1550
Chromium	7440-47-3	3	5.8	16.4	17.1	12.6	3.9	5.8	1.6	2.6	2	27.5	2.3
Cobalt	7440-48-4	4.4 J	5.8	9.3	10.5	5.4 J	3 J	4.3 J	2.1 J	7.5	3.7 J	6.3 J	4.8 J
Copper	7440-50-8	44.6	35.1	74.6	105	67.3	22.2	36.3	33.5	57	37.6	107	49.6
Cyanide	57-12-5	0.37 J	0.2 J	0.23 J	0.14 J	0.23 J	0.13 J	0.54 U	0.12 J	0.57 U	0.088 J	0.27 J	0.14 J
Iron	7439-89-6	17100	20700	38800	41800	33700	16600	35900	17300	26200	24900	20100	16400
Lead	7439-92-1	2.2	42	125	710	132	50.5	1.1 U	1.1 U	1.1 U	1.1 U	83.3	23.3
Magnesium	7439-95-4	2150	2210	2890	3610	3290	1610	3170	2410	3040	2610	2640	2060
Manganese	7439-96-5	366	308	515	547	362	221	332	171	345	268	135	365
Mercury	7439-97-6	0.037 J	0.026 J	0.34	0.67 J	0.11 J	0.041 J	0.042 J	0.038 J	0.034 J	0.048 J	0.9	0.19
Nickel	7440-02-0	1.8 J	4.6	16	19.2	10.2	2.4 J	3.5 J	0.32 J	0.77 J	0.59 J	6	2.2 J
Potassium	7440-09-7	1340	1240	1040	1650	560 J	805	958	1290	1030	1150	597 J	810
Selenium	7782-49-2	3.9 U	4 U	4 U	4.2 U	4.2 U	3.7 U	3.8 U	3.9 U	4 U	4 U	4.6 U	4 U
Silver	7440-22-4	1.1 U	1.2 U	1.2 U	3.5	1.7	0.92 J	1.1 U	1.1 U	1.1 U	1.1 U	1.3 U	1.1 U
Sodium	7440-23-5	127 J	248 J	272 J	249 J	214 J	106 J	361 J	326 J	233 J	196 J	186 J	105 J
Thallium	7440-28-0	0.024 J	0.014 J	0.05 J	0.029 J	0.025 J	0.0094 J	0.039 J	0.027 J	0.026 J	0.021 J	0.027 J	0.026 J
Vanadium	7440-62-2	35.3	53.6	69.3	68.2	41.9	24.3	34.9	31.9	71.8	51.3	40.1	33.7
Zinc	7440-66-6	33.5	102	345	742	430	258	38.4	31.5	27.4	35.8	438	68

Notes:

µg/kg - micrograms per kilogram

mg/kg - milligrams per kilogram

J - estimated value

NJ - tentatively identified value

R- data rejected

U - not detected at corresponding reporting limit

UJ - not detected; the value given as the reporting limit is estimated

Appendix B
Surface Water Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rice

Chemical Name	CAS No.	Location						
		SW-01	SW-02	SW-03	SW-04	SW-05	SW-06	SW-07
Volatile Organic Compounds (µg/L)								
1,1,1-Trichloroethane	71-55-6	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2,2-Tetrachloroethane	79-34-5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2,2-Tetrachloroethane	79-34-5	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2-Trichloroethane	79-00-5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2-Trichloroethane	79-00-5	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
1,1-Dichloroethane	75-34-3	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethene	75-35-4	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2,3-Trichlorobenzene	87-61-6	0.5 UJ	0.5 UJ	0.5 UJ	0.5 U	0.5 U	0.5 U	0.5 U
1,2,4-Trichlorobenzene	120-82-1	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dibromo-3-Chloropropane	96-12-8	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dibromo-3-Chloropropane	96-12-8	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
1,2-Dibromoethane	106-93-4	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dibromoethane	106-93-4	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
1,2-Dichlorobenzene	95-50-1	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloroethane	107-06-2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloroethane	107-06-2	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
1,2-Dichloropropane	78-87-5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloropropane	78-87-5	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
1,3-Dichlorobenzene	541-73-1	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,4-Dichlorobenzene	106-46-7	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,4-Dichlorobenzene	106-46-7	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
2-Butanone	78-93-3	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-Hexanone	591-78-6	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	108-10-1	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Acetone	67-64-1	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Benzene	71-43-2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Benzene	71-43-2	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Bromochloromethane	74-97-5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromodichloromethane	75-27-4	0.5 U	0.5 U	0.5 U	0.5 U	0.72	1	0.38 J
Bromoform	75-25-2	0.5 U	0.5 U	0.5 U	0.5 U	0.43 J	0.64	0.5 U
Bromomethane	74-83-9	0.5 UJ	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Carbon Disulfide	75-15-0	0.5 UJ	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Carbon Tetrachloride	56-23-5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Carbon Tetrachloride	56-23-5	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U

Appendix B
Surface Water Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rice

Chemical Name	CAS No.	Location						
		SW-01	SW-02	SW-03	SW-04	SW-05	SW-06	SW-07
Chlorobenzene	108-90-7	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroethane	75-00-3	0.5 UJ	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroform	67-66-3	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroform	67-66-3	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Chloromethane	74-87-3	0.5 UJ	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
cis-1,2-Dichloroethene	156-59-2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
cis-1,3-Dichloropropene	10061-01-5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Cyclohexane	110-82-7	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Dibromochloromethane	124-48-1	0.5 U	0.5 U	0.5 U	0.5 U	0.94	1.3	0.57
Dichlorodifluoromethane	75-71-8	0.5 UJ	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Ethylbenzene	100-41-4	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Isopropylbenzene	98-82-8	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
m,p-Xylene	179601-23-1	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl Acetate	79-20-9	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl Tert-Butyl Ether	1634-04-4	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylcyclohexane	108-87-2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylene Chloride	75-09-2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
o-Xylene	95-47-6	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Styrene	100-42-5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Tetrachloroethene	127-18-4	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Tetrachloroethene	127-18-4	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Toluene	108-88-3	0.5 U	0.5 U	0.5 U	0.5 UJ	0.5 U	0.5 U	0.5 U
trans-1,2-Dichloroethene	156-60-5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
trans-1,3-Dichloropropene	10061-02-6	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
trans-1,3-Dichloropropene	10061-02-6	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Trichloroethene	79-01-6	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Trichlorofluoromethane	75-69-4	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Vinyl Chloride	75-01-4	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Semi-volatile Organic Compounds (μg/L)								
1,1'-Biphenyl	92-52-4	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
1,2,4,5-Tetrachlorobenzene	95-94-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2,4,5-Trichlorophenol	95-95-4	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2,4,6-Trichlorophenol	88-06-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2,4-Dichlorophenol	120-83-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2,4-Dimethylphenol	105-67-9	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2,4-Dinitrophenol	51-28-5	5 U	5 U	5 U	5 U	5 U	5 U	5 U

Appendix B
Surface Water Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rice

Chemical Name	CAS No.	Location						
		SW-01	SW-02	SW-03	SW-04	SW-05	SW-06	SW-07
2,4-Dinitrotoluene	121-14-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2,4-Dinitrotoluene	121-14-2	0.05 UJ	0.05 UJ	0.05 UJ	0.05 UJ	0.05 UJ	0.05 UJ	0.05 UJ
2,6-Dinitrotoluene	606-20-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2,6-Dinitrotoluene	606-20-2	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
2-Chloronaphthalene	91-58-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2-Chlorophenol	95-57-8	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2-Methylnaphthalene	91-57-6	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2-Methylphenol	95-48-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2-Nitroaniline	88-74-4	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-Nitrophenol	88-75-5	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
3,3'-Dichlorobenzidine	91-94-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
3,3'-Dichlorobenzidine	91-94-1	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
3-Nitroaniline	99-09-2	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4,6-Dinitro-2-Methylphenol	534-52-1	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4-Bromophenyl-Phenylether	101-55-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
4-Chloro-3-Methylphenol	59-50-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
4-Chloroaniline	106-47-8	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
4-Chlorophenyl-Phenylether	7005-72-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
4-Methylphenol	106-44-5	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
4-Nitroaniline	100-01-6	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4-Nitrophenol	100-02-7	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Acenaphthene	83-32-9	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Acenaphthylene	208-96-8	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Acetophenone	98-86-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Anthracene	120-12-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Atrazine	1912-24-9	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Benzaldehyde	100-52-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Benzo(a)anthracene	56-55-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Benzo(a)pyrene	50-32-8	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Benzo(b)fluoranthene	205-99-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Benzo(g,h,i)perylene	191-24-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Benzo(k)fluoranthene	207-08-9	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
bis(2-Chloroethoxy)Methane	111-91-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
bis(2-Chloroethyl) Ether	111-44-4	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
bis(2-Chloroethyl) Ether	111-44-4	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
bis(2-Ethylhexyl)Phthalate	117-81-7	2.5 U	1.1 J	2.5 U	1.7 J	2.5 U	2.5 U	2.5

Appendix B
Surface Water Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rice

Chemical Name	CAS No.	Location						
		SW-01	SW-02	SW-03	SW-04	SW-05	SW-06	SW-07
bis-Chloroisopropyl Ether	108-60-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Butylbenzylphthalate	85-68-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Caprolactam	105-60-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Carbazole	86-74-8	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Chlorophenols	58-90-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Chrysene	218-01-9	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Dibenzo(a,h)anthracene	53-70-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Dibenzofuran	132-64-9	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Diethylphthalate	84-66-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Dimethylphthalate	131-11-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Di-n-Butylphthalate	84-74-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Di-n-Octylphthalate	117-84-0	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Fluoranthene	206-44-0	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Fluorene	86-73-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Hexachlorobenzene	118-74-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Hexachlorobutadiene	87-68-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Hexachlorocyclopentadiene	77-47-4	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Hexachloroethane	67-72-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Indeno(1,2,3-cd)pyrene	193-39-5	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Isophorone	78-59-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Naphthalene	91-20-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Nitrobenzene	98-95-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
N-Nitroso-Di-n-Propylamine	621-64-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
N-Nitroso-Di-n-Propylamine	621-64-7	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U
N-Nitrosodiphenylamine	86-30-6	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Pentachlorophenol	87-86-5	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Pentachlorophenol	87-86-5	0.1 R	0.1 R	0.1 R	0.1 R	0.1 R	0.1 R	0.1 R
Phenanthrene	85-01-8	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Phenol	108-95-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Pyrene	129-00-0	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U

Appendix B
Surface Water Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rice

Chemical Name	CAS No.	Location						
		SW-01	SW-02	SW-03	SW-04	SW-05	SW-06	SW-07
Pesticides/PCBs (µg/L)								
4,4'-DDD	72-54-8	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
4,4'-DDE	72-55-9	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
4,4'-DDT	50-29-3	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
Aldrin	309-00-2	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U
alpha-BHC	319-84-6	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U
alpha-Chlordane	5103-71-9	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U
beta-BHC	319-85-7	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U
delta-BHC	319-86-8	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U
Dieldrin	60-57-1	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
Endosulfan I	959-98-8	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U
Endosulfan II	33213-65-9	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U
Endosulfan Sulfate	1031-07-8	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
Endrin	72-20-8	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
Endrin Aldehyde	7421-93-4	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
Endrin Ketone	53494-70-5	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U
gamma-BHC (Lindane)	58-89-9	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U
gamma-Chlordane	5103-74-2	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U
Heptachlor	76-44-8	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U
Heptachlor Epoxide	1024-57-3	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U	0.003 U
Methoxychlor	72-43-5	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U
Toxaphene	8001-35-2	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Aroclor 1016	12674-11-2	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Aroclor 1221	11104-28-2	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Aroclor 1232	11141-16-5	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Aroclor 1242	53469-21-9	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Aroclor 1248	12672-29-6	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Aroclor 1254	11097-69-1	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Aroclor 1260	11096-82-5	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Aroclor 1262	37324-23-5	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Aroclor 1268	11100-14-4	1 U	1 U	1 U	1 U	1 U	1 U	1 U

Appendix B
Surface Water Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rice

Chemical Name	CAS No.	Location						
		SW-01	SW-02	SW-03	SW-04	SW-05	SW-06	SW-07
Inorganics (µg/L)								
Aluminum	7429-90-5	20 U	20 U	20 U	20 U	40.8	27.4	41.3
Antimony	7440-36-0	2 U	2 U	2 U	2 U	2 U	2 U	2 U
Arsenic	7440-38-2	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Barium	7440-39-3	51.3	45.1	34.4	45	50.5	49.1	49.6
Beryllium	7440-41-7	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Cadmium	7440-43-9	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Calcium	7440-70-2	19900	19600	15800	19800	24500	23800	23500
Chromium	7440-47-3	2 U	2 U	2 U	2 U	2 U	2 U	2 U
Cobalt	7440-48-4	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Copper	7440-50-8	2 U	2 U	3.3	2 U	2.3	2.2	2.1
Cyanide	57-12-5	2.9 J	10 U	4.3 J	10 U	10 U	10 U	10 U
Iron	7439-89-6	200 U	200 U	200 U	200 U	200 U	200 U	200 U
Lead	7439-92-1	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Magnesium	7439-95-4	8230	7850	500 U	7880	9650	9290	9140
Manganese	7439-96-5	45.2	30.6	1.8	44.8	31.8	19.9	33.8
Mercury	7439-97-6	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
Nickel	7440-02-0	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Potassium	7440-09-7	1310	1330	1370	1240	2300	2170	2110
Selenium	7782-49-2	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Silver	7440-22-4	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Sodium	7440-23-5	22100	21300	1910000	22800	29300	28200	27600
Thallium	7440-28-0	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Vanadium	7440-62-2	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Zinc	7440-66-6	2.2	1.5 J	0.52 J	2.3	3.5	3.8	2.9

Notes:

µg/L - micrograms per liter

J - estimated value

R- data rejected

U - not detected at corresponding reporting limit

UJ - not detected; the value given as the reporting limit is estimated

Appendix B
Sediment Analytical Results
Maunabo Groundwater Contamination Site
Manuabo, Puerto Rico

Chemical Name	CAS No.	Location						
		SD-01	SD-02	SD-03	SD-04	SD-05	SD-06	SD-07
Volatile Organic Compounds (µg/kg)								
1,1,1-Trichloroethane	71-55-6	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,1,2,2-Tetrachloroethane	79-34-5	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,1,2-Trichloroethane	79-00-5	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,1-Dichloroethane	75-34-3	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,1-Dichloroethene	75-35-4	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,2,3-Trichlorobenzene	87-61-6	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,2,4-Trichlorobenzene	120-82-1	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,2-Dibromo-3-Chloropropane	96-12-8	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,2-Dibromoethane	106-93-4	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,2-Dichlorobenzene	95-50-1	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,2-Dichloroethane	107-06-2	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,2-Dichloropropane	78-87-5	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,3-Dichlorobenzene	541-73-1	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,4-Dichlorobenzene	106-46-7	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
1,4-Dioxane	123-91-1	120 U	130 U	99 UJ	110 U	140 U	100 U	120 U
2-Butanone	78-93-3	12 U	13 U	9.9 U	11 U	14 U	10 U	12 U
2-Hexanone	591-78-6	12 U	13 U	9.9 U	11 U	14 U	10 U	12 U
4-Methyl-2-Pentanone	108-10-1	12 U	13 U	9.9 U	11 U	14 U	10 U	12 U
Acetone	67-64-1	12 U	13 U	9.9 U	11 U	14 U	10 U	12 U
Benzene	71-43-2	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Bromochloromethane	74-97-5	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Bromodichloromethane	75-27-4	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Bromoform	75-25-2	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Bromomethane	74-83-9	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Carbon Disulfide	75-15-0	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Carbon Tetrachloride	56-23-5	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Chlorobenzene	108-90-7	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Chloroethane	75-00-3	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Chloroform	67-66-3	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Chloromethane	74-87-3	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
cis-1,2-Dichloroethene	156-59-2	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
cis-1,3-Dichloropropene	10061-01-5	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Cyclohexane	110-82-7	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Dibromochloromethane	124-48-1	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Dichlorodifluoromethane	75-71-8	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U

Appendix B
Sediment Analytical Results
Maunabo Groundwater Contamination Site
Manuabo, Puerto Rico

Chemical Name	CAS No.	Location						
		SD-01	SD-02	SD-03	SD-04	SD-05	SD-06	SD-07
Ethylbenzene	100-41-4	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Isopropylbenzene	98-82-8	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
m,p-Xylene	179601-23-1	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Methyl Acetate	79-20-9	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Methyl Tert-Butyl Ether	1634-04-4	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Methylcyclohexane	108-87-2	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Methylene Chloride	75-09-2	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
o-Xylene	95-47-6	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Styrene	100-42-5	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Tetrachloroethene	127-18-4	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Toluene	108-88-3	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
trans-1,2-Dichloroethene	156-60-5	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
trans-1,3-Dichloropropene	10061-02-6	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Trichloroethene	79-01-6	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Trichlorofluoromethane	75-69-4	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Vinyl Chloride	75-01-4	6 U	6.6 U	4.9 U	5.6 U	7.2 U	5 U	5.8 U
Semi-volatile Organic Compounds (μg/kg)								
1,1'-Biphenyl	92-52-4	110 U	110 U	92 U	110 U	120 U	93 U	110 U
1,2,4,5-Tetrachlorobenzene	95-94-3	110 U	110 U	92 U	110 U	120 U	93 U	110 U
2,4,5-Trichlorophenol	95-95-4	110 U	110 U	92 U	110 U	120 U	93 U	110 U
2,4,6-Trichlorophenol	88-06-2	110 U	110 U	92 U	110 U	120 U	93 U	110 U
2,4-Dichlorophenol	120-83-2	110 U	110 U	92 U	110 U	120 U	93 U	110 U
2,4-Dimethylphenol	105-67-9	110 U	110 U	92 U	110 U	120 U	93 U	110 U
2,4-Dinitrophenol	51-28-5	210 U	220 U	180 U	210 U	230 U	180 U	210 U
2,4-Dinitrotoluene	121-14-2	110 U	110 U	92 U	110 U	120 U	93 U	110 U
2,4-Dinitrotoluene	121-14-2	2.1 U	2.2 U	1.8 U	2.1 U	2.3 U	1.8 U	2.1 U
2,6-Dinitrotoluene	606-20-2	110 U	110 U	92 U	110 U	120 U	93 U	110 U

Appendix B
Sediment Analytical Results
Maunabo Groundwater Contamination Site
Manuabo, Puerto Rico

Chemical Name	CAS No.	Location						
		SD-01	SD-02	SD-03	SD-04	SD-05	SD-06	SD-07
2,6-Dinitrotoluene	606-20-2	2.1 U	2.2 U	1.8 U	2.1 U	2.3 U	1.8 U	2.1 U
2-Chloronaphthalene	91-58-7	110 U	110 U	92 U	110 U	120 U	93 U	110 U
2-Chlorophenol	95-57-8	110 U	110 U	92 U	110 U	120 U	93 U	110 U
2-Methylnaphthalene	91-57-6	110 U	110 U	92 U	110 U	120 U	93 U	110 U
2-Methylphenol	95-48-7	110 U	110 U	92 U	110 U	120 U	93 U	110 U
2-Nitroaniline	88-74-4	210 U	220 U	180 U	210 U	230 U	180 U	210 U
2-Nitrophenol	88-75-5	110 U	110 U	92 U	110 U	120 U	93 U	110 U
3,3'-Dichlorobenzidine	91-94-1	110 U	110 U	92 U	110 U	120 U	93 U	110 U
3,3'-Dichlorobenzidine	91-94-1	2.1 U	2.2 U	1.8 U	2.1 U	2.3 U	1.8 U	2.1 U
3-Nitroaniline	99-09-2	210 U	220 U	180 U	210 U	230 U	180 U	210 U
4,6-Dinitro-2-Methylphenol	534-52-1	210 U	220 U	180 U	210 U	230 U	180 U	210 U
4-Bromophenyl-Phenylether	101-55-3	110 U	110 U	92 U	110 U	120 U	93 U	110 U
4-Chloro-3-Methylphenol	59-50-7	110 U	110 U	92 U	110 U	120 U	93 U	110 U
4-Chloroaniline	106-47-8	110 U	110 U	92 U	110 U	120 U	93 U	110 U
4-Chlorophenyl-Phenylether	7005-72-3	110 U	110 U	92 U	110 U	120 U	93 U	110 U
4-Methylphenol	106-44-5	110 U	110 U	92 U	110 U	120 U	93 U	110 U
4-Nitroaniline	100-01-6	210 U	220 U	180 U	210 U	230 U	180 U	210 U
4-Nitrophenol	100-02-7	210 U	220 U	180 U	210 U	230 U	180 U	210 U
Acenaphthene	83-32-9	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Acenaphthylene	208-96-8	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Acetophenone	98-86-2	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Anthracene	120-12-7	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Atrazine	1912-24-9	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Benzaldehyde	100-52-7	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Benzo(a)anthracene	56-55-3	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Benzo(a)pyrene	50-32-8	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Benzo(b)fluoranthene	205-99-2	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Benzo(g,h,i)perylene	191-24-2	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Benzo(k)fluoranthene	207-08-9	110 U	110 U	92 U	110 U	120 U	93 U	110 U
bis(2-Chloroethoxy)Methane	111-91-1	110 U	110 U	92 U	110 U	120 U	93 U	110 U
bis(2-Chloroethyl) Ether	111-44-4	110 U	110 U	92 U	110 U	120 U	93 U	110 U
bis(2-Chloroethyl) Ether	111-44-4	2.1 U	2.2 U	1.8 U	2.1 U	2.3 U	1.8 U	2.1 U
bis(2-Ethylhexyl)Phthalate	117-81-7	110 U	110 U	92 U	110 U	81 J	93 U	110 U

Appendix B
Sediment Analytical Results
Maunabo Groundwater Contamination Site
Manuabo, Puerto Rico

Chemical Name	CAS No.	Location						
		SD-01	SD-02	SD-03	SD-04	SD-05	SD-06	SD-07
bis-Chloroisopropyl Ether	108-60-1	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Butylbenzylphthalate	85-68-7	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Caprolactam	105-60-2	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Carbazole	86-74-8	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Chlorophenols	58-90-2	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Chrysene	218-01-9	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Dibenzo(a,h)anthracene	53-70-3	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Dibenzofuran	132-64-9	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Diethylphthalate	84-66-2	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Dimethylphthalate	131-11-3	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Di-n-Butylphthalate	84-74-2	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Di-n-Octylphthalate	117-84-0	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Fluoranthene	206-44-0	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Fluorene	86-73-7	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Hexachlorobenzene	118-74-1	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Hexachlorobutadiene	87-68-3	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Hexachlorocyclopentadiene	77-47-4	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Hexachloroethane	67-72-1	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Indeno(1,2,3-cd)pyrene	193-39-5	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Isophorone	78-59-1	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Naphthalene	91-20-3	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Nitrobenzene	98-95-3	110 U	110 U	92 U	110 U	120 U	93 U	110 U
N-Nitroso-Di-n-Propylamine	621-64-7	110 U	110 U	92 U	110 U	120 U	93 U	110 U
N-Nitroso-Di-n-Propylamine	621-64-7	2.1 U	2.2 U	1.8 U	2.1 U	2.3 U	1.8 U	2.1 U
N-Nitrosodiphenylamine	86-30-6	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Pentachlorophenol	87-86-5	210 UJ	220 UJ	180 UJ	210 UJ	230 UJ	180 UJ	210 UJ
Pentachlorophenol	87-86-5	4.3 R	4.4 R	3.6 R	4.2 R	4.7 R	3.7 R	4.3 R
Phenanthrene	85-01-8	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Phenol	108-95-2	110 U	110 U	92 U	110 U	120 U	93 U	110 U
Pyrene	129-00-0	110 U	110 U	92 U	110 U	120 U	93 U	110 U

Appendix B
Sediment Analytical Results
Maunabo Groundwater Contamination Site
Manuabo, Puerto Rico

Chemical Name	CAS No.	Location						
		SD-01	SD-02	SD-03	SD-04	SD-05	SD-06	SD-07
Pesticides/PCBs (µg/kg)								
4,4'-DDD	72-54-8	0.29 R	0.22 U	0.18 U	0.21 U	0.31 J	0.19 U	0.22 U
4,4'-DDE	72-55-9	0.46	0.22 U	0.18 U	0.21 U	0.3 J	0.19 U	0.22 U
4,4'-DDT	50-29-3	0.64	0.22 U	0.18 U	0.21 U	0.55 J	0.19 U	0.22 U
Aldrin	309-00-2	0.11 U	0.11 U	0.092 U	0.11 U	0.12 U	0.094 U	0.11 U
alpha-BHC	319-84-6	0.11 U	0.11 U	0.092 U	0.11 U	0.12 U	0.094 U	0.11 U
alpha-Chlordane	5103-71-9	0.11 U	0.11 U	0.092 U	0.11 U	0.12 U	0.094 U	0.11 U
beta-BHC	319-85-7	0.11 U	0.11 U	0.014 J	0.11 U	0.12 U	0.094 U	0.11 U
delta-BHC	319-86-8	0.11 U	0.11 U	0.092 U	0.11 U	0.12 U	0.094 U	0.11 U
Dieldrin	60-57-1	0.22 U	0.22 U	0.18 U	0.21 U	0.24 U	0.19 U	0.22 U
Endosulfan I	959-98-8	0.12	0.11 U	0.092 U	0.11 U	0.12 U	0.094 U	0.11 U
Endosulfan II	33213-65-9	0.22 U	0.22 U	0.18 U	0.21 U	0.24 U	0.19 U	0.22 U
Endosulfan Sulfate	1031-07-8	0.22 U	0.22 U	0.18 U	0.21 U	0.24 U	0.19 U	0.22 U
Endrin	72-20-8	0.22 U	0.22 U	0.18 U	0.21 U	0.24 U	0.19 U	0.22 U
Endrin Aldehyde	7421-93-4	0.22 U	0.22 U	0.18 U	0.21 U	0.24 U	0.19 U	0.22 U
Endrin Ketone	53494-70-5	0.22 U	0.22 U	0.18 U	0.21 U	0.24 U	0.19 U	0.22 U
gamma-BHC (Lindane)	58-89-9	0.11 U	0.11 U	0.092 U	0.11 U	0.12 U	0.094 U	0.11 U
gamma-Chlordane	5103-74-2	0.19 R	0.11 U	0.092 U	0.11 U	0.12 U	0.094 U	0.11 U
Heptachlor	76-44-8	0.19	0.11 U	0.092 U	0.11 U	0.12 U	0.094 U	0.11 U
Heptachlor Epoxide	1024-57-3	0.11 U	0.11 U	0.092 U	0.11 U	0.12 U	0.094 U	0.11 U
Methoxychlor	72-43-5	1.1 U	0.051 J	0.062 J	1.1 U	1.2 U	0.94 U	1.1 U
Toxaphene	8001-35-2	220 U	220 U	180 U	210 U	240 U	190 U	220 U
Aroclor 1016	12674-11-2	43 UJ	44 UJ	36 UJ	42 UJ	46 UJ	36 UJ	43 UJ
Aroclor 1221	11104-28-2	43 UJ	44 UJ	36 UJ	42 UJ	46 UJ	36 UJ	43 UJ
Aroclor 1232	11141-16-5	43 UJ	44 UJ	36 UJ	42 UJ	46 UJ	36 UJ	43 UJ
Aroclor 1242	53469-21-9	43 UJ	44 UJ	36 UJ	42 UJ	46 UJ	36 UJ	43 UJ
Aroclor 1248	12672-29-6	43 UJ	44 UJ	36 UJ	42 UJ	46 UJ	36 UJ	43 UJ
Aroclor 1254	11097-69-1	43 UJ	44 UJ	36 UJ	42 UJ	46 UJ	36 UJ	9.2 J
Aroclor 1260	11096-82-5	43 UJ	44 UJ	36 UJ	42 UJ	46 UJ	36 UJ	43 UJ
Aroclor 1262	37324-23-5	43 UJ	44 UJ	36 UJ	42 UJ	46 UJ	36 UJ	43 UJ
Aroclor 1268	11100-14-4	43 UJ	44 UJ	36 UJ	42 UJ	46 UJ	36 UJ	43 UJ

Appendix B
Sediment Analytical Results
Maunabo Groundwater Contamination Site
Manuabo, Puerto Rico

Chemical Name	CAS No.	Location						
		SD-01	SD-02	SD-03	SD-04	SD-05	SD-06	SD-07
Inorganics (mg/kg)								
Aluminum	7429-90-5	3230 J	2640 J	4040 J	2750 J	5350 J	2810 J	2580 J
Antimony	7440-36-0	1 U	1.1 U	1.1 U	1.1 U	1.1 U	0.99 U	1.2 U
Arsenic	7440-38-2	0.52 U	0.56 U	0.57 U	2.7	0.65	0.5 U	0.62 U
Barium	7440-39-3	41.8	35.5	37.5	45.7	71.9	47	27
Beryllium	7440-41-7	1 U	1.1 U	1.1 U	1.1 U	1.1 U	0.99 U	1.2 U
Cadmium	7440-43-9	0.52 U	0.56 U	0.57 U	0.57 U	0.55 U	0.5 U	0.62 U
Calcium	7440-70-2	1130	1070	1450	1040	1670	1150	1090
Chromium	7440-47-3	2.7 J	3.4 J	3.1 J	4 J	6 J	3 J	2.1 J
Cobalt	7440-48-4	3.6	3.7	2.9	4	7.1	3.4	2.5
Copper	7440-50-8	16.5	14.6	14.6	20.2	31.8	12.6	10.6
Cyanide	57-12-5	0.61 U	0.63 U	0.62 U	0.62 U	0.64 U	0.54 U	0.62 U
Iron	7439-89-6	6910 J	7660 J	8770 J	5220 J	13500 J	6570 J	7210 J
Lead	7439-92-1	0.68 J	0.8 J	0.88 J	1.3 J	2.1 J	0.6 J	0.62 UJ
Magnesium	7439-95-4	1130	1040	1560	913	1890	794	973
Manganese	7439-96-5	267	333	276	295	272	293	237
Mercury	7439-97-6	0.12 U	0.12 U	0.12 U	0.11 U	0.12 U	0.1 U	0.12 U
Nickel	7440-02-0	1.1	1.1	0.84	2.9	2.2	0.87	0.63
Potassium	7440-09-7	428 J	409 J	790	325 J	733	273 J	288 J
Selenium	7782-49-2	2.6 U	2.8 U	2.8 U	2.9 U	2.8 U	2.5 U	3.1 U
Silver	7440-22-4	0.52 U	0.56 U	0.57 U	0.57 U	0.55 U	0.5 U	0.62 U
Sodium	7440-23-5	470 U	432 U	462 U	417 U	514 U	420 U	617 U
Thallium	7440-28-0	0.52 U	0.56 U	0.57 U	0.57 U	0.55 U	0.5 U	0.62 U
Vanadium	7440-62-2	34.8 J	37.7 J	35.1 J	33.5 J	70.6 J	36 J	34.7 J
Zinc	7440-66-6	15.7	14.5	12.2	36.1	30	11.9	12.7

Notes:
µg/kg - micrograms per kilogram
mg/kg - milligrams per kilogram
J - estimated value
R- data rejected
U - not detected at corresponding reporting limit
UJ - not detected; the value given as the reporting limit is estimated

Appendix B
Porewater Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS No.	Location				
		PZ-1	PZ-2	PZ-3	PZ-4	PZ-5
Volatile Organic Compounds (µg/L)						
1,1,1-Trichloroethane	71-55-6	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,1,2,2-Tetrachloroethane	79-34-5	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,1,2,2-Tetrachloroethane	79-34-5	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
1,1,2-Trichloro-1,2,2-Trifluoroethane	76-13-1	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,1,2-Trichloroethane	79-00-5	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,1,2-Trichloroethane	79-00-5	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
1,1-Dichloroethane	75-34-3	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,1-Dichloroethene	75-35-4	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,2,3-Trichlorobenzene	87-61-6	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,2,4-Trichlorobenzene	120-82-1	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dibromo-3-Chloropropane	96-12-8	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dibromo-3-Chloropropane	96-12-8	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
1,2-Dibromoethane	106-93-4	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dibromoethane	106-93-4	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
1,2-Dichlorobenzene	95-50-1	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dichloroethane	107-06-2	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dichloroethane	107-06-2	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
1,2-Dichloropropane	78-87-5	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dichloropropane	78-87-5	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
1,3-Dichlorobenzene	541-73-1	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,4-Dichlorobenzene	106-46-7	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
1,4-Dichlorobenzene	106-46-7	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
2-Butanone	78-93-3	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
2-Hexanone	591-78-6	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
4-Methyl-2-Pentanone	108-10-1	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
Acetone	67-64-1	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
Benzene	71-43-2	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
Bromochloromethane	74-97-5	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Bromodichloromethane	75-27-4	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Bromoform	75-25-2	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Bromomethane	74-83-9	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Carbon Disulfide	75-15-0	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Carbon Tetrachloride	56-23-5	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
Chlorobenzene	108-90-7	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Chloroethane	75-00-3	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Chloroform	67-66-3	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
Chloromethane	74-87-3	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
cis-1,2-Dichloroethene	156-59-2	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
cis-1,3-Dichloropropene	10061-01-5	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Cyclohexane	110-82-7	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Dibromochloromethane	124-48-1	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Dichlorodifluoromethane	75-71-8	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Ethylbenzene	100-41-4	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U

Appendix B
Porewater Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS No.	Location				
		PZ-1	PZ-2	PZ-3	PZ-4	PZ-5
Isopropylbenzene	98-82-8	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
m,p-Xylene	179601-23-1	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Methyl Acetate	79-20-9	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Methyl Tert-Butyl Ether	1634-04-4	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Methylcyclohexane	108-87-2	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Methylene Chloride	75-09-2	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
o-Xylene	95-47-6	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Styrene	100-42-5	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Tetrachloroethene	127-18-4	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
Toluene	108-88-3	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
trans-1,2-Dichloroethene	156-60-5	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
trans-1,3-Dichloropropene	10061-02-6	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
Trichloroethene	79-01-6	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Trichlorofluoromethane	75-69-4	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Vinyl Chloride	75-01-4	0.50 U	0.50 U	0.50 U	0.50 U	0.50 U
Semi-volatile Organic Compounds (µg/L)						
1,1'-Biphenyl	92-52-4	2.5 U	2.5 U	2.5 U	2.5 U	2.5 UJ
1,2,4,5-Tetrachlorobenzene	95-94-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2,4,5-Trichlorophenol	95-95-4	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2,4,6-Trichlorophenol	88-06-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2,4-Dichlorophenol	120-83-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2,4-Dimethylphenol	105-67-9	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2,4-Dinitrophenol	51-28-5	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
2,4-Dinitrotoluene	121-14-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 UJ
2,4-Dinitrotoluene	121-14-2	0.050 U	0.050 U	0.050 U	0.050 U	0.050 U
2,6-Dinitrotoluene	606-20-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 UJ
2,6-Dinitrotoluene	606-20-2	0.050 U	0.050 U	0.050 U	0.050 U	0.050 U
2-Chloronaphthalene	91-58-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2-Chlorophenol	95-57-8	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2-Methylnaphthalene	91-57-6	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2-Methylphenol	95-48-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
2-Nitroaniline	88-74-4	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
2-Nitrophenol	88-75-5	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
3,3'-Dichlorobenzidine	91-94-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
3,3'-Dichlorobenzidine	91-94-1	0.050 U	0.050 U	0.050 U	0.050 U	0.050 U
3-Nitroaniline	99-09-2	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
4,6-Dinitro-2-Methylphenol	534-52-1	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
4-Bromophenyl-Phenylether	101-55-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
4-Chloro-3-Methylphenol	59-50-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
4-Chloroaniline	106-47-8	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
4-Chlorophenyl-Phenylether	7005-72-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
4-Methylphenol	106-44-5	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
4-Nitroaniline	100-01-6	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
4-Nitrophenol	100-02-7	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U

Appendix B
Porewater Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS No.	Location				
		PZ-1	PZ-2	PZ-3	PZ-4	PZ-5
Acenaphthene	83-32-9	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Acenaphthylene	208-96-8	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Acetophenone	98-86-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 UJ
Anthracene	120-12-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Atrazine	1912-24-9	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Benzaldehyde	100-52-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Benzo(a)anthracene	56-55-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Benzo(a)pyrene	50-32-8	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Benzo(b)fluoranthene	205-99-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Benzo(g,h,i)perylene	191-24-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Benzo(k)fluoranthene	207-08-9	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
bis(2-Chloroethoxy)Methane	111-91-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
bis(2-Chloroethyl) Ether	111-44-4	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
bis(2-Chloroethyl) Ether	111-44-4	0.050 U	0.050 U	0.050 U	0.050 U	0.050 U
bis(2-Ethylhexyl)Phthalate	117-81-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
bis-Chloroisopropyl Ether	108-60-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Butylbenzylphthalate	85-68-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 UJ
Caprolactam	105-60-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 UJ
Carbazole	86-74-8	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Chlorophenols	58-90-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Chrysene	218-01-9	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Dibenzo(a,h)anthracene	53-70-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Dibenzofuran	132-64-9	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Diethylphthalate	84-66-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 UJ
Dimethylphthalate	131-11-3	3.0	2.5 U	2.9	2.5 U	2.5 U
Di-n-Butylphthalate	84-74-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 UJ
Di-n-Octylphthalate	117-84-0	2.5 U	2.5 U	2.5 U	2.5 U	2.5 UJ
Fluoranthene	206-44-0	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Fluorene	86-73-7	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Hexachlorobenzene	118-74-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Hexachlorobutadiene	87-68-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Hexachlorocyclopentadiene	77-47-4	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Hexachloroethane	67-72-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 UJ
Indeno(1,2,3-cd)pyrene	193-39-5	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Isophorone	78-59-1	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Naphthalene	91-20-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Nitrobenzene	98-95-3	2.5 U	2.5 U	2.5 U	2.5 U	2.5 UJ
N-Nitroso-Di-n-Propylamine	621-64-7	0.050 U	0.050 U	0.050 U	0.050 U	0.050 U
N-Nitrosodiphenylamine	86-30-6	2.5 U	2.5 U	2.5 U	2.5 U	2.5 UJ
Pentachlorophenol	87-86-5	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U
Phenanthrene	85-01-8	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Phenol	108-95-2	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U
Pyrene	129-00-0	2.5 U	2.5 U	2.5 U	2.5 U	2.5 U

Appendix B
Porewater Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS No.	Location				
		PZ-1	PZ-2	PZ-3	PZ-4	PZ-5
Pesticides/PCBs (µg/L)						
4,4'-DDD	72-54-8	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U
4,4'-DDE	72-55-9	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U
4,4'-DDT	50-29-3	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U
Aldrin	309-00-2	0.0025 U	0.0025 U	0.0025 U	0.0025 U	0.0025 U
alpha-BHC	319-84-6	0.0025 U	0.0025 U	0.0025 U	0.0025 U	0.0025 U
alpha-Chlordane	5103-71-9	0.0025 U	0.0025 U	0.0025 U	0.0025 U	0.0025 U
beta-BHC	319-85-7	0.0025 U	0.0025 U	0.0025 U	0.0025 U	0.0025 U
delta-BHC	319-86-8	0.0039 J	0.0025 U	0.0025 U	0.0025 U	0.0025 U
Dieldrin	60-57-1	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U
Endosulfan I	959-98-8	0.0025 R	0.0025 R	0.0025 R	0.0025 R	0.0025 R
Endosulfan II	33213-65-9	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U
Endosulfan Sulfate	1031-07-8	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U
Endrin	72-20-8	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U
Endrin Aldehyde	7421-93-4	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U
Endrin Ketone	53494-70-5	0.0050 U	0.0050 U	0.0050 U	0.0050 U	0.0050 U
gamma-BHC (Lindane)	58-89-9	0.0025 U	0.0025 U	0.0025 U	0.0025 U	0.0025 U
gamma-Chlordane	5103-74-2	0.0025 U	0.0025 U	0.0025 U	0.0025 U	0.0025 U
Heptachlor	76-44-8	0.0028 R	0.0048 NJ	0.0025 U	0.0025 U	0.0025 U
Heptachlor Epoxide	1024-57-3	0.0025 U	0.0025 U	0.0025 U	0.0025 U	0.0025 U
Methoxychlor	72-43-5	0.025 U	0.025 U	0.025 U	0.025 U	0.025 U
Toxaphene	8001-35-2	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Aroclor 1016	12674-11-2	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Aroclor 1221	11104-28-2	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Aroclor 1232	11141-16-5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Aroclor 1242	53469-21-9	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Aroclor 1248	12672-29-6	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Aroclor 1254	11097-69-1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Aroclor 1260	11096-82-5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Aroclor 1262	37324-23-5	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Aroclor 1268	11100-14-4	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U

Appendix B
Porewater Analytical Results
Maunabo Groundwater Contamination Site
Maunabo, Puerto Rico

Chemical Name	CAS No.	Location				
		PZ-1	PZ-2	PZ-3	PZ-4	PZ-5
Inorganics (µg/L)						
Aluminum	7429-90-5	20.0 UJ	20.0 UJ	79.3 J	861 J	61.6 J
Antimony	7440-36-0	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U
Arsenic	7440-38-2	1.0 U	1.0 U	1.0 U	1.0 U	0.28 J
Barium	7440-39-3	62.5 J	47.3 J	47.2 J	124 J	59.2 J
Beryllium	7440-41-7	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Cadmium	7440-43-9	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Calcium	7440-70-2	24900	26300	26000	26000	29300
Chromium	7440-47-3	2.0 U	2.0 U	2.0 U	2.0 U	2.0 U
Cobalt	7440-48-4	1.0 U	1.0 U	1.0 U	0.59 J	1.0 U
Copper	7440-50-8	1.6 J	1.0 J	1.2 J	4.8	1.8 J
Cyanide	57-12-5	10.0 U	10.0 U	10.0 U	10.0 U	4.3 J
Iron	7439-89-6	200 U	200 U	83.4 J	1060	61.0 J
Lead	7439-92-1	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Magnesium	7439-95-4	9730	10200	9830	21700	11300
Manganese	7439-96-5	15.1	0.49 J	4.2	53.8	3.2
Mercury	7439-97-6	0.20 U	0.20 U	0.20 U	0.20 U	0.20 U
Nickel	7440-02-0	1.0 U	1.0 U	1.0 U	0.26 J	1.0 U
Potassium	7440-09-7	1360	1310	1290	1590	1990
Selenium	7782-49-2	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U
Silver	7440-22-4	1.0 U	1.0 U	1.0 U	1.0 U	1.0 U
Sodium	7440-23-5	25800	25900	25600	27000	30400
Thallium	7440-28-0	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ	1.0 UJ
Vanadium	7440-62-2	2.1 J	3.1 J	4.3 J	5.2	3.7 J
Zinc	7440-66-6	2.9 J	1.3 J	1.6 J	4.3 J	3.0 J

Notes:

µg/L - micrograms per liter

J - estimated value

R- data rejected

U - not detected at corresponding reporting limit

UJ - not detected; the value given as the reporting limit is estimated

Appendix C

Fate, Transport, and Toxicity of Chemicals of Potential Concern

Appendix C

Fate, Transport, and Toxicity of Chemicals of Potential Concern

Introduction

Discussions on the fate, transport, and toxicity of chemicals of potential concern (COPCs) are presented below, and are limited only to detected chemicals for which concentrations were above their respective screening value, or those for which no screening value was located. Chemicals eliminated from further evaluation as noted in Section 5.3 are not included.

C.1 Inorganics

Fate, transport and toxicity of inorganic COPCs are discussed in the following subsections.

C.1.1 Aluminum

Fate and Transport: Because of its strong reactivity, aluminum is not found as a free metal in nature. Aluminum has only one oxidation state (+3), thus its behavior in the environment depends on its ordination chemistry and the surrounding conditions. In soils, a low pH generally results in an increase in aluminum mobility. In water, an equilibrium with a solid phase is established that controls the extent of aluminum dissolution (ATSDR 2008a).

Plants vary in their ability to remove aluminum from soils, although bioconcentration factors for plants are generally less than one. Biomagnification of aluminum in terrestrial food chains does not appear to occur. There is no data on the biomagnification of aluminum in aquatic food chains (ATSDR 2008a).

Toxicity: The nervous system may be a target area for aluminum. Aluminum may also interact with neuronal DNA to alter gene expression and protein formation. Mammalian studies do not indicate that aluminum affects reproduction although some developmental effects have been reported in mammals (ATSDR 2008a). In animals, ingestion of aluminum at levels of 1,400 parts per million (ppm) lowered levels of inorganic phosphorus in blood and bones (HSDB 2010). Severe aluminum intoxication, characterized by lethargy, anorexia, or death, was observed in rats following parenteral or oral administration of aluminum hydroxide, chloride, or sulfate. Other studies have found that intratracheal instillation of aluminum salts or metallic aluminum powder has produced pulmonary fibroses (HSDB 2010). Lethal dose (LD) 50 values for aluminum ingestion are typically unavailable because aluminum is only sparingly absorbed from the gut, and because death occurs from intestinal blockage due to precipitated aluminum species rather than systemic aluminum toxicity (HSDB 2010).

C.1.2 Barium

Fate and Transport: Barium is widely distributed in both terrestrial and aquatic environments. Although it is found in most aquatic environments, most barium precipitates out in the form of insoluble salts (EPA 1986). Transport of barium by suspended sediments in lotic water bodies may be significant. Barium is not expected to bioconcentrate significantly in plants or freshwater aquatic organisms.

Barium occurs naturally in most surface water and groundwater. In groundwater and surface water, barium is likely to precipitate out of solution as an insoluble salt (EPA 1986). The chemical form of barium largely dictates its adsorption into soils and sediments. Barium in sediments is found largely in the relatively insoluble form of barium sulfate and also in the insoluble form of barium carbonate. Humic and fulvic acid have not been found to increase the mobility of barium (ATSDR 2007).

Toxicity: The oral toxicity of barium compounds depends on their solubility. The soluble compounds, which include the chloride, nitrate, and hydroxide are the most toxic. The insoluble sulfate and carbonate are relatively nontoxic. The cardiovascular system appears to be a primary target of barium toxicity in humans and laboratory animals (ATSDR 2007). Barium has no known function in vertebrates, although it has been reported that insufficient dietary barium may depress growth rate in laboratory animals (NRC 1980).

Barium interacts with potassium, calcium, and magnesium. It has been shown that barium produces hypokalemia (i.e., lowered blood potassium), possibly by causing the build-up of intracellular potassium, and that symptoms of cardiotoxicity, muscle weakness, and paralysis resulting from barium exposure can be reversed in humans by potassium treatment (ATSDR 2007).

C.1.3 Cadmium

Fate and Transport: Cadmium is a naturally occurring, rare, but widely distributed element. It may enter the environment through mining, ore processing, and smelting of zinc and zinc-lead ores; the recovery of metal by processing scrap; the casting of alloys for coating products (telephone cables, electrodes, sprinkling systems, fire alarms, switches, relays, circuit breakers, solder, and jewelry); the production of sewage-sludges and phosphate fertilizers; the combustion of coal and fossil fuels, and the use of paint, pigment, and batteries, (Eisler 1985).

In the environment, cadmium occurs primarily as a divalent metal that is insoluble in water, but its chloride and sulfate salts are freely soluble (Eisler 1985). If released or deposited on soil, cadmium is largely retained in the surface layers; it is adsorbed to soil but to a much lesser extent than most other heavy metals. Because adsorption increases with pH and organic content, solublization and leaching is more apt to occur under acid conditions in sandy soil.

The bioavailability of cadmium is dependent on a number of factors including pH, Eh (redox potential), concentration, and chemical speciation (Eisler 1985). Cadmium enters the food chain through uptake by plants from soils; only cadmium in soil solution is thought to be directly available for uptake (Shore and Douben 1994). The main routes of cadmium absorption for mammals are via respiration and ingestion, including dietary transfer. Factors that appear to affect dietary cadmium absorption from the gastrointestinal tract include age, sex, chemical form, and protein concentration of the diet, and is inversely proportional to dietary intake of other metals, particularly iron and calcium (Friberg 1979).

Toxicity: Cadmium does not have any known essential or beneficial biological function (Eisler 1985). It is classified as a B1, probable human carcinogen. Cadmium replaces essential metals (e.g., zinc) at critical sites on proteins and enzymes and may inhibit a variety of enzymatic reactions. Concentrations increase with the age of an organism and eventually act as a cumulative poison (Hammons et al. 1978).

Cadmium is readily taken up from soil through plant roots and interferes with root uptake of essential elements including iron, manganese, magnesium, nitrogen, and possibly calcium. Symptoms of cadmium toxicity in plants include poor root development, reduced conductivity of stems, tissue necrosis, reduced growth, and reduced photosynthetic activity due to impaired stomatal functioning (Bazzaz et al. 1974, as cited in EPA 2005a; Efroymson et al. 1997). Mammals and birds are more resistant to effects of cadmium contamination than are aquatic organisms, but may show toxicological effects including growth retardation, anemia, impaired kidney function, poor reproductive capacity, and birth defects (Eisler 1985).

C.1.4 Chromium

Fate and Transport: Chromium is widely distributed in the earth's crust. Major atmospheric emissions of chromium are from the chromium alloy and metal producing industries; lesser amounts come from coal combustion, municipal incinerators, cement production, and cooling towers (Towill et al. 1978, as cited in Eisler 1986). Chromium in phosphates used as fertilizers may be an important source of chromium in soil, water, and some foods (Langard and Norseth 1979, as cited in Eisler 1986).

Chromium can exist in oxidation states ranging from Cr (+2) to Cr (+6), but it is most frequently converted to the relatively stable chromium (+3) and chromium (+6) oxidation states (Eisler 1986). The solubility and bioavailability of chromium are governed by soil pH and organic complexing substances, although organic complexes play a more significant role (James and Bartlett 1983a,b, as cited in Eisler 1986). Hexavalent chromium is not strongly sorbed to soil components and may be mobile in groundwater; however, it is quickly reduced to chromium (+3) in poorly drained soils having a high organic content.

Chromium may biomagnify, although because of its relatively low membrane permeability, chromium (+3) generally does not have the biomagnification potential of chromium (+6). However, organo-trivalent chromium compounds may have very different bioaccumulation tendencies; some cases of large degrees of accumulation by aquatic and terrestrial plants and animals in lower trophic levels have been documented, though the mechanism of accumulation remains largely unknown (Eisler 1986).

Toxicity: The biological effects of chromium depend upon the chemical form, solubility, and valence. Chromium (+3) is the form usually found in biological materials. Chromium is beneficial, but not essential, to higher plants (Eisler 1986). It functions as an essential element in mammals and birds by maintaining vascular integrity and efficient glucose, lipid, and protein metabolism (Steven et al. 1976, as cited in Eisler 1986). However, chromium may also be mutagenic, carcinogenic, and teratogenic. While EPA regards all chromium compounds as toxic, the most toxic tend to be strongly oxidizing forms of chromium (+6). Toxic effects of chromium in plants include the disruption of carbon, nitrogen, phosphorus, and iron metabolism; inhibition of photosynthesis and reduced growth; poorly developed roots; and curled leaves. Chromium toxicity in birds and mammals is associated with abnormal histopathology, enzyme activity and blood chemistry; lowered resistance to pathogenic organisms; behavioral modifications; disrupted feeding; and alterations in population structure (Eisler 1986). However, in mammalian species, chromium is considered one of the least toxic trace elements, because hexavalent chromium is converted to trivalent chromium under the normal stomach conditions of low pH (Irwin et al. 1997).

C.1.5 Copper

Fate and Transport: Copper is an essential element and widely distributed in nature (Amdur et al. 1993). Naturally occurring concentrations of copper have been calculated at 70 ppm in the earth's crust and 0.001 to 0.02 ppm in seawater (HSDB 2010). Artificial sources of copper include smelting processes and non-ferrous metal production. The terrestrial fate of copper is related to degree of weathering, the nature and intensity of soil formation, drainage, pH, re-dox potential and organic content (HSDB 2010). The relationship between pH and copper determines the fate of copper where alkaline conditions in soil and surface water promote precipitation while acidic conditions favor solubility of copper.

Toxicity: Copper is caustic, and acute toxicity is primarily related to this property (Hatch 1978). Copper is an essential element for animals and is a component of many metalloenzymes and respiratory pigments (Demayo et al. 1982). It is also essential for iron utilization and functions in enzymes for energy production, connective tissue formation, and pigmentation. Excess copper ingestion leads to accumulation in tissues, especially in the liver. High levels of copper modify hepatic metabolism (Brooks 1988), which may lead to inability of the liver to store and excrete additional copper. When the liver concentration exceeds a certain level, the metal is released into the blood, causing hemolysis and jaundice. High copper levels also inhibit essential metabolic enzymes (Demayo et al. 1982). Toxic symptoms appear when the liver accumulates 3 to 15 times the normal level of copper (Demayo et al. 1982).

C.1.6 Iron

Fate and Transport: Iron is the fourth most common element in the earth's crust. Iron concentrations in soil can range from 0.2 to 55 percent and can vary significantly even within localized areas (Bodek et al. 1988). Iron is used primarily in the production of steel and other alloys. The iron ore formed is dependent upon the availability of other chemicals (e.g., sulfur is required to produce FeS2, or pyrite). Important iron ores are hematite, magnetite, limonite and siderite.

Under typical environmental conditions, iron is found in either the more soluble and bioavailable divalent form (ferrous iron or Fe^{+2}) or the less soluble and less bioavailable trivalent form (ferric iron or Fe^{+3}) (EPA 2003). Valence state is determined by the pH and Eh of the system. In general, oxidizing and alkaline conditions promote the precipitation of insoluble ferric oxide or hydroxic precipitates, while acidic and reducing conditions promote the solution of ferrous compounds. Iron does not bioaccumulate because it is regulated by the body and excess iron is eliminated.

Toxicity: Iron is an essential micro-nutrient to most forms of life, from plants to man, and is internally regulated by most organisms. In plants, iron is a critical component of energy transformations needed for syntheses and other life processes of the cells. In animals, iron is a component of various enzymes and proteins, including hemoglobin, which carries oxygen to the cells.

If excess ferrous iron is present, toxicity to plants may occur. However, sensitivity to iron is highly dependent upon plant species. In animals, adverse effects of iron toxicity may include renal failure and hepatic cirrhosis. The mechanism of toxicity begins with acute mucosal cell damage and absorption of ferrous ions directly into circulation, resulting in capillary endothelial cell damage to the liver (Shacklette and Boerngen 1984). However, the greatest environmental threat posed by high iron concentrations typically relates to the precipitation of iron oxides in aquatic systems, resulting in the smothering and embedding of the bottom substrate of the water body. Iron in soil generally does not impart significant ecological risk.

C.1.7 Lead

Fate and Transport: Lead is present in the earth's crust at a concentration of approximately 15 grams per ton (g/ton). Lead naturally enters the environment from lead bearing minerals and median lead concentrations in soil are 15 to 16 micrograms (µg). The processes of erosion and leaching may transfer lead from soil into surface waters and the atmosphere. Anthropogenic sources via smelting, mining, ore processing, refining use, recycling or disposal, are the most common release sources of lead into the environment. In soil, lead is typically in the upper 2 to 5 centimeter (cm) and leaching is not expected to be significant. In water, precipitation of lead is significant if the pH is relatively high where the amount of lead that can remain in water is related to pH and dissolved salt content. Metallic lead will simply sink into the sediment and will adsorb to organic matter and clay minerals or precipitate out as an insoluble salt. Bioconcentration does not appear to be high in fish although bioconcentration factors (BCF) for various saltwater bivalves, mollusks, diatoms and phytoplankton have been found to range from 1.24 after 56 days in hard clams to 3.40 after 130 days in mussels (HSDB 2010).

Toxicity: Lead does not biomagnify to a great extent in food chains, although accumulation by plants and animals has been extensively documented (Wixson and Davis 1993; Eisler 1988). Older organisms typically contain the highest tissue lead concentrations, with the majority of the accumulation occurring in the bony tissue of vertebrates (Eisler 1988).

The toxic effects of lead on aquatic and terrestrial organisms are extremely varied and include mortality, reduced growth and reproductive output, blood chemistry alterations, lesions, and behavioral changes. However, many effects exhibit general trends in their toxic mechanism. Generally, lead inhibits the formation of heme, adversely affects blood chemistry, and accumulates at hematopoietic organs (Eisler 1988). At high concentrations near levels causing mortality, marked changes to the central nervous system (CNS) occur prior to death (Eisler 1988).

C.1.8 Manganese

Fate and Transport: Manganese does not occur as a free metal in the environment but is a component of numerous minerals. Elemental manganese and inorganic manganese compounds have negligible vapor pressures, but may exist in air as suspended particulate matter derived from industrial emissions or the erosion of soil. Removal from the atmosphere is mostly through gravitational settling. The transport and partitioning of manganese in water are controlled by the solubility of the specific chemical form present. The metal may exist in water in any of four oxidation states (2+, 3+, 4+, or 7+). Divalent manganese (Mn+2) predominates in most waters (pH 4 to 7), but may become oxidized at a pH greater than 8 or 9. Manganese is often transported in moving water as suspended sediments. The tendency of soluble manganese compounds to adsorb to soils and sediments depends mainly on the cation exchange capacity (CEC). Cation exchange capacity is related to soil's organic content and texture; where CEC increases with organic matter and in finer textured soils. Increasing pH also increases CEC. Adsorption of manganese and other metals to soil colloid particles increases with increasing CEC (Brady 1974). Manganese in water may be significantly bioconcentrated at lower trophic levels. However, biomagnification in the food chain may not be significant (ATSDR 2008b).

Toxicity: Manganese is a common element that is essential for normal physiologic functioning in all animal species. In most animals, the amount of manganese absorbed across the gastrointestinal tract is variable and less than 5 percent. There does not appear to be a marked difference between manganese ingested in food or in water. One of the key determinants of absorption appears to be dietary iron intake, with low iron levels leading to increased manganese absorption. This is probably because both iron and manganese are absorbed by the same transport system in the gut in aquatic and terrestrial species (ATSDR 2008b).

In studies where repeated oral doses were given to animals in an attempt to induce chronic manganese disease, moderate doses did not induce any injury (HSDB 2010). Female rats fed a concentration of 154 to 1004 mg/kg dry weight during pregnancy and weaning had fetuses with elevated concentrations of manganese in the liver although no gross malformations were observed (HSDB 2010). When manganese was administered orally to monkeys, degenerative, histological changes (demyelination of the posterior column) were observed in the chiasma and spinal cord (HSDB 2010).

C.1.9 Mercury

Fate and Transport: Mercury has been used by man for thousands of years, most recently as a fungicide in agriculture, in the manufacture of chlorine, sodium hydroxide, electronics, and plastics, as a slime control agent in the pulp and paper industry, and in mining and smelting operations (Eisler 1987). Mercury is persistent in the environment, with organisms in contaminated habitats showing elevated mercury burdens for as long as 100 years after the pollution source has been removed (Eisler 1987).

Mercury is present in the environment in both inorganic and organic forms. Inorganic mercury exists in three valence states: mercuric (Hg2+), mercurous (Hg1+), and elemental (Hg) mercury. Inorganic mercury compounds are less toxic than organomercury compounds; the mercuric ion is the most toxic inorganic chemical form (Clarkson and Marsh 1982). However, the inorganic forms are readily converted to organic forms by bacteria commonly present in the environment. The organomercury compound of greatest concern is methylmercury, due to its high stability, lipid solubility, and ability to penetrate membranes in living organisms (Beijer and Jernalov 1979). Mercury can become methylated biologically or chemically. Microbial methylation of mercury occurs most rapidly under anaerobic conditions, which are common in wetlands and aquatic sediments but may also be found in soils.

Most mercury detected in biological tissues is present in the form of methylmercury (Huckabee et al. 1979), which is known to biomagnify in food chains.

Toxicity: Mercury is a highly toxic mutagenic and teratogenic compound with no known natural biological function. A number of toxic effects of mercury exposure have been reported, although little information is available regarding its effect on terrestrial plants. In birds, mammals, and fish, mercury acts as a potent neurotoxin, resulting in impaired muscular coordination, vision, and hearing; depressed growth and reproduction; weight loss; and apathy, with early developmental stages being the most sensitive (Eisler 1987). Other effects include changes in enzyme activity levels and histopathology. In mammals, methylmercury irreversibly destroys the neurons of the CNS.

C.1.10 Vanadium

Fate and Transport: Elemental vanadium does not occur free in nature but is a component of dozens of different minerals and fossil fuels (EPA 2005b). Anthropogenic sources include acid-mine leachate, sewage sludge, and fertilizers. It is also a by-product of petroleum refining and the combustion of hydrocarbon fuels (EPA 2005b). Vanadium is principally used as an alloy constituent, especially in steel, as well as in pigment manufacturing, photography, and insecticides.

Vanadium can take various valence states, from +2 to +5. It is found in rocks and soil in the relatively insoluble trivalent form, and as vanadates of a variety of metals in the +5 oxidation state (EPA 2005b). It can also form both cationic and anionic salts. The release of vanadium to soil occurs as a result of the weathering of rocks and from soil erosion, both of which generally convert the less-soluble trivalent form to the more-soluble pentavalent form. Mobility of vanadium in soils is determined by pH, Eh, and organic content. In contrast to most metals, vanadium is fairly mobile in neutral or alkaline soils and less mobile in acidic soils. Soluble vanadium in soils appears to be easily taken up by plant roots (Hopkins et al. 1977, as cited by EPA 2005b). Vanadium is not considered bioaccumulative.

Toxicity: Toxicity of vanadium has not been demonstrated in plants. In animals, the toxic action is largely confined to the respiratory tract, because inhalation is the most common route of exposure; absorption of vanadium through the gastrointestinal tract of animals is low. Inhalation of vanadium damages the alveolar macrophages by decreasing the macrophage membrane integrity; damaged macrophages inhibit the ability of the respiratory system to clear itself of other particles. However, ingestion of high concentrations of vanadium compounds (V2O5) may lead to acute poisoning characterized by marked effects on the nervous system, hemorrhage, paralysis, convulsions, and respiratory depression. Subacute exposures at high concentrations may adversely affect the liver, adrenals, and bone marrow (Klassen et al. 1986). In vitro experiments in mice indicate that the mechanism of toxicity of vanadium is by inhibiting sodium-potassium ATPase activity, which inhibits the sodium-potassium pump. This pump is necessary for the transport of material across cell membranes (Nechay and Saunders 1978).

C.1.11 Zinc

Fate and Transport: Zinc occurs naturally in the earth's crust. It is used primarily in the production of brass and other alloys, galvanization of iron and steel products, and formulation of white pigments. It is also used as a fungicide in agriculture and is applied to soils to prevent zinc deficiency (Eisler 1993). Anthropogenic releases of zinc in the environment occur through smelting and ore processing, mine drainage, sewage, combustion of solid wastes and fossil fuels, road surface runoff, corrosion of zinc alloys and galvanized surfaces, and erosion of agricultural soils (Eisler 1993).

Zinc is not found free in nature, but often occurs in the +2 oxidation state as zinc sulfide, zinc carbonate, or zinc oxide. Zinc compounds also exist in the particulate phase in the atmosphere and are physically removed from the air by wet or dry deposition. Zinc is strongly adsorbed to soil at pH 5 or greater, and zinc compounds have low mobility in most soils (Blame and Brummer 1991). Clay minerals, hydrous oxides, and pH are the most important factors controlling zinc solubility. Soluble forms of zinc are readily absorbed by plants. Uptake is dependent on soil type; for example, uptake is lower in coarse loamy soils than in fine loamy soils (Chang et al. 1983, as cited by Eisler 1993). Zinc is essential for normal growth and reproduction in plants and animals and is regulated by the body.

Toxicity: Because zinc is an essential element, maintaining a balance between excess and insufficient zinc is important. Zinc deficiency occurs in many species of plants and animals and has severe adverse effects on all stages of growth, development, reproduction, and survival (Eisler 1993). Zinc is a component of several essential enzymes that regulate the biosynthesis and catabolic rate of RNA and DNA.

A wide safety margin appears to exist between required and toxic zinc intakes. However, high levels of zinc can cause copper deficiency and interfere with metabolism of calcium and iron (Goyer 1986, as cited by Eisler 1993). Terrestrial plants growing in soil with high zinc concentrations (such as beneath corroded galvanized fencing or near zinc smelters) showed poor seedling establishment and decreased photosynthesis, respiration, and seedling root elongation, resulting in negative impacts on measures of species richness and abundance (Nash 1975, as cited by Eisler 1993). Zinc poisoning has also been documented in a variety of animal species, usually through the ingestion of zinc-containing products such as galvanized metal objects, zinc containing coins, and skin and sunblock preparations containing zinc oxide (Eisler 1993).

The pancreas and bone seem to be the primary targets of zinc toxicity in birds and mammals. Signs of acute poisoning include impaired reproduction, anorexia, depression, enteritis, diarrhea, decreased milk yield, decreased growth, excessive eating and drinking and, in severe cases, convulsions and death (Ogden et al. 1988, as cited in Eisler 1993). Zinc preferentially accumulates in bone, where it induces osteomalacia, a softening of bone caused by a deficiency of calcium, phosphorus, and other minerals (Kaji et al. 1988). Pancreatic effects include reduced activity of digestive enzymes, cytoplasmic vacuolation, cellular atrophy, and cell death (Lu and Combs 1988, Kazacos and Van Vleet 1989).

C.2 Volatile Organic Compounds

Fate, transport and toxicity of volatile organic compound COPCs are discussed in the following subsections.

C.2.1 Bromodichloromethane

Fate and Transport: Bromodichloromethane is a colorless, nonflammable liquid (ATSDR 1999). Bromodichloromethane is primarily used as a chemical intermediate and solvent. However, the most predominant manmade source of bromodichloromethane is its inadvertent formation during chlorination treatment processes of water. Bromodichloromethane may occur naturally in algae and is subsequently released to sea water. Vapor-phase bromodichloromethane will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 205 days. If released to soil, bromodichloromethane is expected to have high to moderate mobility. Studies have shown that biodegradation may not be an important environmental fate process. If released into water, bromodichloromethane is expected to adsorb to suspended solids and sediment. When released to surface water, estimated volatilization half-lives range from 4 hours to 5 days (HSDB 2010).

Toxicity: Few studies were located regarding the toxicity of bromodichloromethane. In general, studies on animals showed that exposure to high concentrations of bromodichloromethane can damage the liver and kidneys and affect the brain (ATSDR 1999). Studies on rats and mice orally administered bromodichloromethane resulted in LD50s ranging from 916 mg/kg to 1820 mg/kg.

C.2.2 Dibromochloromethane

Fate and Transport: Dibromochloromethane is a colorless to yellow, heavy, nonflammable, liquid with a sweet odor. Small amounts are formed naturally by plants in the ocean. The compound is somewhat soluble in water and readily evaporated into the air. Most of the dibromochloromethane that enters the environment is formed as byproducts when chlorine is added to drinking water to kill bacteria. Dibromochloromethane may be biodegrade and does not bioaccumulate (ASTDR 2005).

Toxicity: Few studies were located regarding the toxicity of dibromochloromethane. Animals exposed to high concentrations of dibromochloromethane developed liver and kidney injuries; exposure to lower concentrations do not appear to seriously affect the brain, liver, or kidneys. Dibromochloromethane does affect fertility in humans; however, studies on animals suggest that reproductive affects are low (ASTDR 2005). Studies on rats and hamsters orally administered dibromochloromethane resulted in LD50s ranging from 145 mg/kg to 760 mg/kg. A lethal concentration (LC) 50 of 53 milligrams per liter (mg/L) for the common carp was determined after an 8 hour test (HSDB 2010).

C.3 Semi-volatile Organic Compounds

Fate, transport and toxicity of semi-volatile organic compound COPCs are discussed in the following subsections.

C.3.1 Carbazole

Fate and Transport: Release of carbazole into the environment occurs primarily by emissions from waste incineration; tobacco smoke; petroleum, coal and wood combustion; and in the effluents of wood treating facilities. Carbazole occurs naturally in coal, petroleum and peat and will be released into the environment through incomplete combustion of these materials (HSDB 2010). With an average Koc value of 637, it is assumed that carbazole is not very mobile in soil but may biodegrade in soil and water if specific degrading bacteria are present (HSDB 2010). Bioconcentration and volatilization are not important in aquatic systems.

Toxicity: An LD50 of greater than 5,000 mg/kg was calculated for rats in an oral dosing study (HSDB 2010). Male (50) and female (50) mice were fed a pellet diet containing technical grade carbazole (purity, 96 percent) at concentrations of 0.6, 0.3 or 0.15 or 0.0 (control) for 96 weeks. Upon examination, neoplastic lesions were found in the liver and forestomach, and the liver lesions were classified as neoplastic nodules and hepatocellular carcinomas (HSDB 2010). The incidence of lesions was significantly greater in the highest dosed animals.

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